87

Cost Estimates of Operating Onsite Spent Fuel Pools After Final Reactor Shutdown

S. R. Rod

August 1991

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes **any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.** Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401. FTS 626-8401.

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

COST ESTIMATES OF OPERATING ONSITE
SPENT FUEL POOLS AFTER FINAL
REACTOR SHUTDOWN

S. R. Rod

August 1991

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

EXECUTIVE SUMMARY

This report presents estimates of the annual costs of operating spent fuel pools at nuclear power stations after the final shutdown of one or more onsite reactors. Its purpose is to provide basic spent fuel storage cost information for use in evaluating DOE's reference nuclear waste management system, as well as alternate systems. The basic model of an independent spent fuel storage installation (ISFSI) used in this study was based on General Electric Corporation's Morris Operation and was modified to reflect mean storage capabilities at an unspecified, or "generic," U.S. reactor site. Cost data for the model came from several sources, including both operating and shutdown nuclear power stations and existing ISFSIs. Duke Power Company has estimated ISFSI costs based on existing spent fuel storage costs at its nuclear power stations. Similarly, nuclear material handling facilities such as the Morris Operation, the West Valley Demonstration Project, and the retired Humbolt Bay nuclear power station have compiled spent fuel storage cost data based on years of operating experience.

Consideration was given to the following factors that would cause operating costs to vary among pools: 1) the number of spent fuel pools at a given reactor site, 2) the number of operating and shutdown reactors onsite, 3) geographic location, and 4) pool storage capacity. Tables are included that show the best estimates of the costs (in 1989 dollars) of operating spent fuel pools at reactor sites with one, two, and three reactors shut down. Entries in the tables include only the cost of operating inactive pools, which are no longer receiving spent fuel from reactors (i.e., operating in a "storage-only" mode). Costs associated with pools actively receiving spent fuel from onsite operating reactors were assumed to be included in routine plant operation costs. Operating one inactive "storage-only" pool was estimated to cost about \$3,670,000 annually; two inactive pools were estimated to cost about \$4,130,000 annually; and three inactive pools were estimated to cost about \$4,800,000 annually. Costs are essentially independent of reactor type.

Monte Carlo simulations were performed to estimate the variations in the inactive pool operating costs (listed in Table 2.1) due to the geographic and pool capacity factors. The statistics for individual cost variables were derived from the references cited for the original cost estimates. The range of cost variation for a site with a single spent fuel pool and all reactors shut down is summarized in Table 2.2.

CONTENTS

EXECUTIVE SUMMARY	iii
1.0 INTRODUCTION	1.1
2.0 CONCLUSIONS	2.1
2.1 NOMINAL SPENT FUEL POOL OPERATION COSTS	2.1
2.2 TREATMENT OF UNCERTAINTY	2.2
2.3 ANNUAL COST PER UNIT STORAGE CAPACITY	2.2
3.0 METHODOLOGY	3.1
3.1 DESCRIPTION OF THE MODEL ISFSI	3.1
3.2 OPERATING COST CATEGORIES	3.1
3.3 COST ADJUSTMENTS FOR GEOGRAPHIC VARIATION	3.2
3.4 COST ADJUSTMENTS FOR POOL CAPACITY VARIATION	3.5
3.5 COSTS FOR SECOND AND THIRD POOLS ON THE SITE	3.8
3.6 ADDITIONAL ASSUMPTIONS	3.11
4.0 REFERENCES	4.1
APPENDIX A - BACKGROUND SURVEY CONTACTS	A.1
APPENDIX B - MORRIS OPERATION ORGANIZATION CHART	B.1

FIGURES

2.1 Costs of Operating Spent Fuel Pools: Variation Due to Geographic Factors	2.3
2.2 Costs of Operating Spent Fuel Pools: Variation Due to Differing Pool Capacities	2.3
2.3 Costs of Operating Spent Fuel Pools: Overall Variability	2.4
2.4 Annual Cost-per-kgU of Operating Spent Fuel Pools: Distribution Among U.S. Reactor Sites	2.4
3.1 At-Reactor Spent Fuel Storage Capacities	3.6
3.2 Spent Fuel Pool Operation Cost Estimates	3.7

TABLES

2.1 Estimated Annual Operation Costs of Onsite Spent Fuel Storage at Shutdown Reactors ...	2.1
2.2 Spent Fuel Pool Operation Cost Variations: Single-Pool Site with All Reactors Shut Down	2.2
3.1 Spent Fuel Pool Annual Costs for Long-Term Operation at a 750-MTU-Capacity ISFSI	3.3
3.2 Geographically Adjusted Annual Cost for a Generic 750-MTU-Capacity ISFSI Location	3.5
3.3 Final Adjusted Annual Operating Cost of an Average Capacity ISFSI at a Generic U.S. Location	3.6
3.4 Annual Costs for Long-Term Operation of an Additional Spent Fuel Pool at an ISFSI	3.9
3.5 Annual Costs for Long-Term Operation of a Second Additional Spent Fuel Pool at an ISFSI	3.10

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM) is responsible for developing a system for the management of high-level radioactive waste and spent nuclear fuel in accordance with the Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 (NWPAA). Pacific Northwest Laboratory (PNL)^(a) is assisting DOE in conducting the system engineering and system integration activities required to develop, design, and deploy the federal waste management system. In the context of system engineering studies, there is a need to estimate 1) the costs of onsite spent fuel storage at shutdown reactors, and 2) the sensitivities of these cost estimates to spent fuel allocation and receipt timing.

The need for pool operating cost estimates is generic across several current and proposed studies, including the Reference System Performance Evaluation (RSPE), which is intended to provide the reference point from which comparisons of alternative system configurations and their performances can be made.

To evaluate the cost-effectiveness of the reference system and alternative configurations, information is needed on the cost of various aspects of spent nuclear fuel management. Specifically, data on the cost of storing spent fuel elements on the sites at which they were produced and after final reactor shutdown are required input for the system cost evaluation model, "System Engineering Cost Analysis Capability" (Humphreys et al. 1990).

This report presents estimates of the annual costs (in 1989 dollars) of operating spent fuel pools at nuclear power stations after the final shutdown of one or more onsite reactors. It is based on a survey of existing literature and consultations with key personnel at operating spent fuel storage facilities. The report includes assumptions, references, and supporting information.

For compatibility with the data table used by the System Engineering Cost Analysis Model (SECAM) (Humphreys et al. 1990), the cost values used in this report have been modeled after the PNL "MRS Systems Study Task G Report" (Wood et al. 1989, p. B.6). Values for estimating annual operating costs of onsite spent fuel storage at shutdown reactors can be used as input to SECAM as long as they are carefully chosen to match the intended case(s) of the SECAM analysis.

Information on spent fuel pools and wet-storage independent spent fuel storage installations (ISFSIs) was reviewed to identify the necessary cost categories for operating such a facility long-term. The broad cost categories identified include 1) personnel costs, 2) non-personnel costs (e.g., supplies and equipment), 3) plant services, 4) utilities (electric power only), and 5) administrative costs. Cost estimates were drawn from several data sources, both published and unpublished reports and interviews with cognizant experts. References are listed in the reference section at the end of this report; for information on interviews, see Appendix A.

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

Annual operating costs were estimated for the model (i.e., typical) facility. General Electric's (GE) Morris Operation, an ISFSI near Morris, Illinois, was used as a typical wet-storage facility (GE 1990). Its licensed capacity is close to the mean capacity of all spent fuel pools at commercial reactors (DOE 1989). In recent years, it has been operating virtually in a storage-only (e.g., ISFSI) mode. The facility's operation and maintenance programs appear to be typical of those that would be encountered at future wet-storage ISFSIs. The most significant alteration made to create the model ISFSI from the Morris Operation was the staffing level. Personnel requirements for the model ISFSI were increased over those of the Morris Operation to better reflect the likely staffing levels needed for utilities to comply with regulations governing ISFSIs starting operation in the future (based on discussions with cognizant personnel at commercial nuclear power plants).

The results of the study are presented in Section 2.0, and the cost estimation methodology is described in detail in Section 3.0.

2.0 CONCLUSIONS

This section summarizes the findings of the study, including 1) best estimates of the annual costs for utilities to operate spent fuel pools as independent spent fuel storage installations (ISFSIs) at reactor sites with one, two, and three reactors shut down; 2) the uncertainty associated with these cost estimates due to geographic and pool capacity factors; and 3) the variation of annual cost-per-kgU (storage capacity in kilograms of uranium) among U.S. commercial reactor sites.

2.1 NOMINAL SPENT FUEL POOL OPERATION COSTS

Table 2.1 shows the best estimates of the annual costs of operating spent fuel pools as ISFSIs at reactor sites with one, two, and three reactors shut down. For compatibility with the data table used by the System Engineering Cost Analysis Model (SECAM), the information in the table has been adapted from the format of Table B.1 of the PNL report, "MRS Systems Study Task G Report" (Wood et al. 1989, p. B.6). However, it was found in this current study that spent fuel storage costs depended on the number of spent fuel pools on the site as well as on the number of onsite reactors. Consequently, there

Table 2.1. Estimated Annual Operation Costs of Onsite Spent Fuel Storage at Shutdown Reactors^(a)

Situation at Reactor Site		Number of Reactors Onsite		
Reactor Status	Pool Status	1	2	3
1 reactor shut down	1 pool onsite:	\$3,670,000	(b)	(c)
	2 pools onsite:		\$460,000 ^(d)	\$460,000 ^(d)
	3 pools onsite:			\$460,000 ^(d)
2 reactors shut down	1 pool onsite:		\$3,670,000	(c)
	2 pools onsite:		\$4,130,000	\$460,000 ^(d)
	3 pools onsite:			\$460,000 ^(d)
	- 1 pool shut:			\$1,130,000 ^(d)
3 reactors shut down	- 2 pools shut:			
	1 pool onsite:			(c)
	2 pools onsite:			\$4,130,000
	3 pools onsite:			\$4,800,000

(a) Annual operating costs are in 1989 dollars. Only costs associated with "steady-state," long-term spent fuel storage are included. Costs associated with receiving and shipping spent fuel elements are excluded (e.g., additional manpower, equipment, etc., for either receiving/unloading or loading and shipping transport casks). Other costs not included are:

- Facility decommissioning costs, including the cost of final disposition of liquid and solid radioactive wastes currently accumulated on the site for eventual disposal at decommissioning.
- Local, county, and state fees and taxes; notably, property taxes.
- For additional pools: extra insurance, licensing, inspection, and regulatory costs.

(b) In this case, the spent fuel pool operation costs would continue to be included in operating plant costs.

(c) This configuration does not exist at U.S. reactor sites.

(d) This assumes that utility chooses to shut down (i.e., cease to receive spent fuel) the pool(s) associated with the shutdown reactor(s), while one or more reactors continue to operate at the site. In this case, the operation costs of the pools remaining active would continue to be included in operating plant costs.

are more cost entries in Table 2.1 than there are in the equivalent table in the Task G report. Nonetheless, values from Table 2.1 can be used as input to SECAM as long as table values are carefully chosen to match the intended case(s) of the SECAM analysis.

Entries in the table reflect the total cost of operating all inactive pools (i.e., pools not receiving spent fuel from reactors). In general, the cost allocation that is the basis for Table 2.1 was conducted with security costs assigned to an operating reactor if possible. A 3-reactor/3-pool site with two reactors shut down would incur a cost of \$460,000 per year for the first inactive pool and \$670,000 per year for the second inactive pool, totaling \$1,130,000 per year. Both a 2-reactor/2-pool site and a 3-reactor/2-pool site with all reactors shut down would cost \$3,670,000 + \$460,000 or \$4,130,000 per year. A 3-reactor/3-pool site with all reactors shut down would cost \$3,670,000 + \$460,000 + \$670,000 or \$4,800,000 per year.

2.2 TREATMENT OF UNCERTAINTY

To estimate the uncertainty associated with the cost estimates listed in Table 2.1, a Monte Carlo simulation of the distribution of costs due to the geographic and pool capacity factors is described in Section 3.0, "Methodology." The statistics for individual cost variables were derived from Wood et al. (1989) and Humphreys et al. (1990). The results are summarized in Table 2.2 and in Figures 2.1, 2.2, and 2.3.

Uncertainty in this analysis ascribed to geographic and capacity factors could be reduced by specifying the relevant values for individual sites in a more detailed assessment (i.e., a site-specific version of Table 2.1). Site-specific data are available to help specify costs for a given location and pool capacity. At this time, however, SECAM cannot utilize site-specific cost data.

2.3 ANNUAL COST PER UNIT STORAGE CAPACITY

As can be seen in Table 2.2 and Figure 2.2, pool capacity affects the annual operating cost. While total operating costs tend to increase only slightly as pool storage capacity increases (a twenty-fold

**Table 2.2. Spent Fuel Pool Operation Cost Variations:^(a)
Single-Pool Site with All Reactors Shut Down**

<u>Variations Due to</u>	<u>Expected Value</u>	<u>Minimum Result</u>	<u>Maximum Result</u>	<u>Standard Deviation</u>
Geographic Factors (see Figure 2.1)	\$3,900,000	\$2,870,000	\$5,180,000	\$330,000
Capacity Factors (see Figure 2.2)	\$3,670,000	\$2,850,000	\$5,260,000	\$440,000
Combined Factors ^(b) (see Figure 2.3)	\$3,670,000	\$2,270,000	\$6,000,000	\$550,000

(a) Based on 2,000-sample Monte Carlo simulation.

(b) Combined geographic and capacity factors.

Figure 2.1. Costs of Operating Spent Fuel Pools: Variation Due to Geographic Factors

Figure 2.2. Costs of Operating Spent Fuel Pools: Variation Due to Differing Pool Capacities (Generally, operating costs increase as pool capacity increases.)

Figure 2.3. Costs of Operating Spent Fuel Pools: Overall Variability

Figure 2.4. Annual Cost-per-kgU of Operating Spent Fuel Pools: Distribution Among U.S. Reactor Sites (Generally, operating costs-per-kgU decrease as pool capacity increases.)

increase in pool capacity yields only a two-fold increase in annual operating cost), operating cost-per-kgU decreases dramatically as the pool capacity increases. Figure 2.4 shows the estimated annual operating costs-per-kgU of total onsite storage capacity for U.S. commercial reactor sites. The expensive outliers are all older facilities with relatively small pools. Nonetheless, ISFSI operating costs-per-kgU per year still will probably vary by about a factor of three among the main population of U.S. nuclear power plants.

There is a lot of confusion about the way the world is changing. The world is changing in many ways, and it is important to understand the changes that are taking place. The world is becoming more global, and there is a lot of competition between different countries. The world is also becoming more diverse, and there are many different cultures and languages. The world is changing in many ways, and it is important to understand the changes that are taking place.

10

11

12

13

3.0 METHODOLOGY

This section describes the methods used to estimate the annual costs of operating one or more spent fuel pools at shutdown reactor sites. First, the unit cost components for operating a spent fuel pool or pools as an independent spent fuel storage installation (ISFSI) were categorized and estimated from collected reference material. These unit costs were then applied to a model of a typical future utility-operated ISFSI, including staffing levels, material consumption, utility requirements, etc. The initial estimates of annual operating costs were for a single spent fuel pool. Similar cost estimates were made for sites with one or two additional spent fuel pools.

3.1 DESCRIPTION OF THE MODEL ISFSI

General Electric's Morris Operation, an ISFSI near Morris, Illinois (adjacent to the Dresden Nuclear Power Station), was used as a typical wet-storage facility. Its licensed capacity of 750 metric tons of uranium (MTU) is only slightly greater than the mean capacity, 595 MTU, of all spent fuel pools at commercial reactors (DOE 1989; GE 1990). It has been operating with this capacity since 1976 and in recent years has been operating virtually in a steady-state storage-only mode, since spent fuel shipping operations have been curtailed. This facility currently operates under the requirements of 10 CFR 72, which contains licensing requirements for ISFSIs. Morris' operations, maintenance programs, personnel requirements, and costs are probably typical of those that would be encountered at future wet-storage ISFSIs.

To estimate costs for future utility-operated ISFSIs, the Morris Operation's personnel requirements were increased to reflect the likely staffing levels needed for utilities to comply with the regulations that will govern ISFSIs in the future (based on discussions with cognizant experts at commercial nuclear power plants).

3.2 OPERATING COST CATEGORIES

The following operating cost categories were compiled from several references:

Personnel:

- Administration
- Plant Operation
- Plant Maintenance
- Plant Services
- Security
- Custodial Services

Non-Personnel:

- Operation and Maintenance -
 - Instrumentation and electrical maintenance
 - Mechanical maintenance

Chemistry
Radioactive waste management system

Services -
Radiation protection and environmental monitoring

Utilities -
Electric power (only)

General and Administrative -
Licensing and inspection
Nuclear liability insurance

Costs associated with these categories were estimated for the prototype facility described later in this section (cost references are noted in Table 3.1).

Table 3.1 lists the costs that make up the total estimated annual cost of operating a spent fuel pool (or pools) as an ISFSI. Several electric utilities have estimated various costs associated with spent fuel storage. For example, Duke Power Company conducted an internal (proprietary) study estimating the costs of operating an ISFSI based on existing spent fuel storage pools costs at its nuclear power stations.^(a) Similarly, nuclear material handling facilities such as the Morris Operation,^(b) the West Valley Demonstration Project,^(c) and the retired Humbolt Bay nuclear power station have compiled spent fuel storage cost data based on years of operating experience. Table 3.1 was constructed from those sources, both published and unpublished reports, and interviews with cognizant experts listed in the reference section and in Appendix A.

3.3 COST ADJUSTMENTS FOR GEOGRAPHIC VARIATION

After costs for the model facility were estimated, adjustments were made to reflect more nearly a national average cost; for instance,

1. Duke Power's personnel costs^(d) were divided by 0.8 because the southeast region's personnel costs are about 80% of the U.S. average (Ball 1986; Claiborne et al. 1989).

-
- (a) Memorandum from D. E. Oglesby to M. Robinson, July 21, 1989. "O&M Cost Estimate for Support Required to Use Spent Fuel Storage Pool as an ISFSI." Duke Power Company, Charlotte, North Carolina.
 - (b) Personal communication with J. Kesman, Plant Operation and Maintenance Manager, Morris Operation, June 11, 1990. General Electric Corporation, Morris, Illinois.
 - (c) Personal communication with B. Conners, Fuel Program Manager, West Valley Nuclear Services Company, June 19, 1990. Westinghouse Electric Corporation, West Valley, New York.
 - (d) Internal communication, T. W. Wood to S. R. Rod, May 22, 1990. "Ops Cost After Shutdown." Pacific Northwest Laboratory, Richland, Washington.

Table 3.1. Spent Fuel Pool Annual Costs for Long-Term Operation at a 750-MTU-Capacity ISFSI (Case 1 - No operating reactors onsite and one spent fuel pool. Table entries in 1989 dollars)

1. Personnel costs (items 1-35 represent Morris Operation staffing levels)

Entry No.	Position Description	Annual Cost
1	Facility Manager ^(a)	\$70,000
2	Plant Services Manager (Health Physics) ^(a)	52,000
3	Senior Services Technician #1 ^(b,c)	38,800
4	Senior Services Technician #2 ^(b,c)	38,800
5	Senior Services Technician #3 ^(b,c)	38,800
6	Operation & Maintenance Manager ^(a)	52,000
7	Maintenance Engineer ^(b,c)	44,600
8	Senior Maintenance Technician #1 ^(b,c)	36,000
9	Senior Maintenance Technician #2 ^(b,c)	36,000
10	Senior Maintenance Technician #3 ^(b,c)	36,000
11	Maintenance Technician ^(b,c)	26,700
12	Operations Engineer ^(b,c)	47,600
13	Lead Operations Technician #1 ^(b,c)	36,000
14	Lead Operations Technician #2 ^(b,c)	36,000
15	Lead Operations Technician #3 ^(b,c)	36,000
16	Lead Operations Technician #4 ^(b,c)	36,000
17	Operation & Maintenance (O&M) Technician #1 ^(b,c)	26,700
18	O&M Technician #2 ^(b,c)	26,700
19	O&M Technician #3 ^(b,c)	26,700
20	O&M Technician #4 ^(b,c)	26,700
21	O&M Technician #5 ^(b,c)	26,700
22	O&M Technician #6 ^(b,c)	26,700
23	Safety/Security Engineer ^(b,c)	44,600
24	Secretary #1 ^(b,c)	17,900
25	Personnel Administrator ^(b,c)	36,100
26	Buyer ^(a)	35,000
27	Security Guard #1 ^(b,c)	22,800
28	Security Guard #2 ^(b,c)	22,800
29	Security Guard #3 ^(b,c)	22,800
30	Security Guard #4 ^(b,c)	22,800
31	Security Guard #5 ^(b,c)	22,800
32	Security Guard #6 ^(b,c)	22,800
33	Security Guard #7 ^(b,c)	22,800
34	Security Guard #8 ^(b,c)	22,800
35	Custodian #1 ^(a)	16,000

(a) Based on comparable positions.

(b) Internal communication, T. W. Wood to S. R. Rod, May 22, 1990. "Ops Cost After Shutdown." Pacific Northwest Laboratory, Richland, Washington.

(c) Memorandum from D. E. Oglesby to M. Robinson, July 21, 1989. O&M Cost Estimate for Support Required to Use Spent Fuel Storage Pool as an ISFSI." Duke Power Company, Charlotte, North Carolina.

Table 3.1. (contd)

1. Personnel costs (items 36-46 represented additional staffing for future ISFSI over Morris Levels)

Entry No.	Position Description	Annual Cost
36	Plant Services Manager (Environmental) ^(c,d,e,f)	52,000
37	Site Engineer (Licensing & Compliance) ^(c,d,e,f)	36,100
38	Site Engineer (Quality Assurance) ^(c,d,e,f)	47,600
39	Quality Assurance Technician ^(c,d,e,f)	23,800
40	Administration Clerk ^(c,d,e,f)	17,900
41	Secretary #2 ^(c,d,e,f)	17,900
42	Secretary #3 ^(c,d,e,f)	17,900
43	Security Supervisor #1 ^(c,d,e,f)	27,100
44	Security Supervisor #2 ^(c,d,e,f)	27,100
45	Security Supervisor #3 ^(c,d,e,f)	27,100
46	Custodian #2 ^(c,d,e,f)	16,000
Direct Personnel Costs		\$1,464,000
Overhead & Benefits: rate = 0.475		695,400
Total Personnel Costs:		\$2,159,400

	Cost Category	Annual Cost
2. Operation & Maintenance:		
	Instrumentation & Electrical Maintenance (materials & supplies)	\$112,000
	Mechanical Maintenance (materials & supplies)	130,000
	Chemistry (materials & supplies)	251,000
	Radwaste System	
	Onsite Processing (supplies)	53,000
	Contract Removal & Disposal	75,000
3. Services:		
	Radiation Protection/Environmental Monitoring (materials & supplies)	25,000
4. Utilities:		
	Electric Power (2,000,000 kWh/yr * \$0.08/kWh)	160,000
5. General & Administrative (Wood et al. 1989):		
	Licensing & Inspection	20,000
	Nuclear Liability & Property Insurance	400,000
Total Non-Personnel Costs:		\$1,226,000
Total Annual Operating Cost:		\$3,385,400

(c) Memorandum from D. E. Oglesby to M. Robinson, July 21, 1989. "O&M Cost Estimate for Support Required to Use Spent Fuel Storage Pool as an ISFSI." Duke Power Company, Charlotte, North Carolina.

(d) Personal communication with B. Conners, Fuel Program Manager, West Valley Nuclear Services Company, June 19, 1990. Westinghouse Electric Corporation, West Valley, New York.

(e) Personal communication with J. Kesman, Plant Operation and Maintenance Manager, Morris Operation, June 11, 1990. General Electric Corporation, Morris, Illinois.

(f) Personal communications with R. I. Smith, June 1-21, 1990. Pacific Northwest Laboratory, Richland, Washington.

2. Electric power costs from GE's Morris Operation were divided by 1.17 because Illinois' (specifically, the Chicago region's) electricity costs are approximately 117% of the national average (Census 1990).

Table 3.2 shows the results of these adjustments.

Although regional factors for material costs were available in Ball (1986), material cost adjustments were not made because the regional variations were far less than the uncertainty inherent in the material cost estimation method used in this study. In a Duke Power internal memorandum,^(a) the costs of materials and supplies were estimated by multiplying the personnel cost in individual departments by 0.40 (since materials and supplies costs are assumed to be equal to 40% of personnel costs).

Table 3.2. Geographically Adjusted Annual Cost for a Generic 750-MTU-Capacity ISFSI Location (Case 1 - no operating reactors onsite and one spent fuel pool. Table entries in 1989 dollars)

Cost Category	Initial Annual Cost Estimate ^(a)	Adjusted Annual Cost
Personnel Costs (Ball 1986; Claiborne 1989; Census 1990) ^(b,c)	\$2,159,400	\$2,699,300
Total Materials and Supplies (Ball 1986; Claiborne 1989; Census 1990) ^(d)	\$646,000	\$646,000
Utilities (Electric Power) (Ball 1986; Claiborne 1989; Census 1990) ^(e)	\$160,000	\$136,800
General & Administrative:		
Licensing & Inspection	\$20,000	\$20,000
Nuclear Liability & Property Insurance ^(f)	\$400,000	\$400,000
Total Annual Operating Cost (initial estimate) for a 750-MTU-capacity pool at a Generic Location in the U.S.	\$3,385,400	\$3,902,100

(a) Based on Table 3.1.

(b) Memorandum from D. E. Oglesby to M. Robinson, July 21, 1989. "O&M Cost Estimate for Support Required to Use Spent Fuel Storage Pool as an ISFSI." Duke Power Company, Charlotte, North Carolina.

(c) Duke Power's estimated personnel costs were divided by 0.8 to account for the fact that the southeast region's personnel costs were approximately 80% of the U.S. average (in 1988).

(d) Personal communication with B. Connors, Fuel Program Manager, West Valley Nuclear Services Company, June 19, 1990. Westinghouse Electric Corporation, West Valley, New York.

(e) Morris Operation's electricity costs were divided by 1.17 to account for the fact that Illinois' electric utility costs were approximately 117% of the U.S. average (in 1988).

(f) Personal communications with J. P. Marone, Senior Vice President and General Counsel, American Nuclear Insurers, August 8, 1990. Farmington, Connecticut.

3.4 COST ADJUSTMENTS FOR POOL CAPACITY VARIATION

Table 3.3 summarizes adjustments made to account for variations in spent fuel capacities among reactor sites.

- (a) Memorandum from D. E. Oglesby to M. Robinson, July 21, 1989. "O&M Cost Estimate for Support Required to Use Spent Fuel Storage Pool as an ISFSI." Duke Power Company, Charlotte, North Carolina.

Table 3.3. Final Adjusted Annual Operating Cost of an Average Capacity (595-MTU-Capacity) ISFSI at a Generic U.S. Location (Case 1 - no operating reactors onsite and one spent fuel pool. Table entries in 1989 dollars)

Cost Category	Annual Cost
Capacity Cost Factor: Adjustment for a Mean Capacity ISFSI:	
Capacity of Morris Operation's Pool (750 MTU) ^(a)	
Mean U.S. Commercial Spent Fuel Pool Capacity (595 MTU) ^(b)	
Annual Cost vs. Capacity Formula; \$ 1989 = F(MTU):	
\$2,363,000 + \$1,286 * (pool capacity in MTU) ^(c)	
Annual Operating Cost of a 750-MTU pool (per formula)	\$3,328,000
Annual Operating Cost of a 595-MTU Pool (per formula)	\$3,128,000
Capacity Adjustment Factor (\$3,128,000 ÷ \$3,328,000): 0.94	
Adjusted Annual Operating Cost of an Average-Capacity (595 MTU) ISFSI at a Generic U.S. Location (0.94 X 3,902,100)	\$3,670,000

(a) Based on data from GE (1990).

(b) Based on data from DOE (1989).

(c) Based on data from McCartney and Cairns (1984) and expressed in 1989 dollars (see Subsection 3.4).

Figure 3.1. At-Reactor Spent Fuel Storage Capacities (Mean Capacity = 595 MTU)

There are presently 103 spent fuel pools in operation at 77 commercial nuclear power plants in the U.S., as shown in Figure 3.1 (DOE 1989). These pools have fuel storage capacities ranging from 81 MTU to 1,570 MTU, based on the nominal heavy metal content of spent PWR and BWR fuel assemblies (Hill et al. 1983; DOE 1989). An Electric Power Research Institute (EPRI) report on the cost of spent fuel storage shows a moderate correlation between pool operation cost and pool capacity (McCartney and Cairns 1984).

In Figure 3.2, the data from McCartney and Cairns (1984) are expressed in 1989 dollars, converted from the 1983 dollars used in the original report by applying "GNP deflator" factors from 1983 through 1988, as shown below (Census 1990):

<u>Year</u>	<u>GNP Deflator</u>
1983	0.039
1984	0.037
1985	0.030
1986	0.026
1987	0.032
<u>1988</u>	<u>0.033</u>
Compounded 1983-1988	0.214

Figure 3.2. Spent Fuel Pool Operation Cost Estimates (McCartney and Cairns 1984)

To adjust the cost estimate presented in Table 3.3 to reflect the mean capacity of U.S. spent fuel pools, 595 MTU, the cost of the 750-MTU prototype facility was modified as follows:

A linear regression formula was derived from data in McCartney and Cairns (1984) (see Figure 3.2):

$$\begin{aligned}\text{Cost (in 1989) dollars} &= f(\text{capacity}) \\ &= \$2,363,000 + \$1,286 \times \text{capacity (in MTU)}\end{aligned}$$

$$\begin{aligned}\text{Therefore:} \quad f(595 \text{ MTU}) &= \$3,128,000 \text{ per year} \\ f(750 \text{ MTU}) &= \$3,328,000 \text{ per year}\end{aligned}$$

From these two annual costs, a cost-scaling factor based on pool capacity was calculated:

$$\text{Cost-scaling factor} = \frac{\$3,128,000}{\$3,328,000} \sim 0.940$$

The geographically adjusted pool operation cost was multiplied by the capacity cost-scaling factor to yield the final adjusted annual operating cost for an average capacity spent fuel pool in a generic location in the U.S., shown at the end of Table 3.3:

$$\begin{aligned}\text{adjusted cost} &= \$3,900,000 \times 0.940 \\ &= \$3,666,000 \text{ per year} \\ &\sim \$3,670,000 \text{ per year}\end{aligned}$$

3.5 COSTS FOR SECOND AND THIRD POOLS ON THE SITE

At some nuclear power plants there is more than one operating reactor and more than one active spent fuel pool. Also, as more reactors cease operating in the future, there will be sites with no operating reactors, but more than one spent fuel pool operating in long-term storage (i.e., steady-state shutdown) mode. Tables 3.4 and 3.5 show the costs of operating a second and third spent fuel pool for these situations.

Table 3.4 shows the annual cost of operating one additional shutdown spent fuel pool. Additional personnel costs include a lead operations technician for each shift [requiring four full-time-equivalent (FTE) positions] and the associated overhead (Wood et al. 1989). The only additional non-personnel costs included were for materials and supplies (estimated to be 40% of additional personnel costs)^{(a)(b)}

-
- (a) Internal communication, T. W. Wood to S. R. Rod, May 22, 1990. "Ops Cost After Shutdown." Pacific Northwest Laboratory, Richland, Washington.
 - (b) Memorandum from D. E. Oglesby to M. Robinson, July 21, 1989. "O&M Cost Estimate for Support Required to Use Spent Fuel Storage Pool as an ISFSI." Duke Power Company, Charlotte, North Carolina.

Table 3.4. Annual Costs for Long-Term Operation of an Additional Spent Fuel Pool at an ISFSI
(Case 2 - operating reactor(s) onsite, with one active spent fuel pool -or-
no operating reactors, with one inactive spent fuel pool already in operation;
entries are in 1989 dollars)

Part 1) Prototype Facility

A) Additional Personnel Costs:

<u>Position Description</u>	<u>Annual Cost</u>	<u>Totals</u>
Lead Operations Technician #1 ^(a,b)	\$36,000	
Lead Operations Technician #2 ^(a,b)	36,000	
Lead Operations Technician #3 ^(a,b)	36,000	
Lead Operations Technician #4 ^(a,b)	<u>36,000</u>	
Subtotal:	144,000	
Overhead: rate = 0.475	<u>68,400</u>	
Staff salaries + overhead subtotal:	\$212,400	\$212,400

B) Additional Non-Personnel Costs:^(a,b,c)

Materials & Supplies:	85,000	
Electric Power: ^(d)	<u>160,000</u>	
Non-personnel Cost Subtotal:	\$245,000	<u>\$245,000</u>
Total Annual Cost:		\$457,400

Part 2) Adjustments for Geographic and Capacity Variations

A) Geographic Variations

<u>Cost Category</u>	<u>Initial Cost Estimate</u>	<u>Adjusted Cost</u>
Personnel Costs:	\$212,400	\$265,500 (\$212,400/0.8)
Materials & Supplies:	85,000	85,000
Electric Power:	<u>160,000</u>	<u>137,000</u> (\$160,000/1.17)
Total Annual Cost:	\$457,400	\$487,500 (average U.S. annual cost of the 750-MTU capacity storage pool)

B) Adjusted Cost of an Average
Capacity (595 MTU) Pool at a
Generic U.S. Location:

\$458,250 (\$487,500 * 0.940)
~ \$460,000

(a) Internal communication, T. W. Wood to S. R. Rod, May 22, 1990. "Ops Cost After Shutdown." Pacific Northwest Laboratory, Richland, Washington.

(b) Memorandum from D. E. Oglesby to M. Robinson, July 21, 1989. "O&M Cost Estimate for Support Required to Use Spent Fuel Storage Pool as an ISFSI." Duke Power Company, Charlotte, North Carolina.

(c) Personal communications with R. I. Smith, June 1-21, 1990. Pacific Northwest Laboratory, Richland, Washington.

(d) Personal communication with J. Kesman, Plant Operation and Maintenance Manager, Morris Operation, June 11, 1990. General Electric Corporation, Morris, Illinois.

Table 3.5. Annual Costs for Long-Term Operation of a Second Additional Spent Fuel Pool at an ISFSI
(Case 3 - operating reactor(s) onsite, with one active pool and one shutdown pool
already in operation -or- no operating reactors, with two shutdown spent fuel pools
already in operation; entries are in 1989 dollars)

Part 1) Prototype Facility

A) Additional Personnel Costs:

<u>Position Description</u>	<u>Annual Cost</u>	<u>Totals</u>
Lead Operations Technician #1	\$36,000	
Lead Operations Technician #2	36,000	
Lead Operations Technician #3	36,000	
Lead Operations Technician #4	36,000	
Security Guard #1	22,800	
Security Guard #2	22,800	
Security Guard #3	22,800	
Security Guard #4	22,800	
Subtotal:	\$235,200	
Overhead: rate = 0.475	111,700	
Staff salaries + overhead subtotal:	\$346,900	\$346,900

B) Additional Non-personnel Costs:

Materials & Supplies:	\$138,800 ^(a)	
Electric Power:	160,000	
Non-personnel Cost Subtotal:	\$298,800	\$298,800
Total Annual Cost:		\$645,700

Part 2) Adjustments for Geographic and Capacity Variations

A) Geographic Variations

<u>Cost Category</u>	<u>Initial Cost Estimate</u>	<u>Adjusted Cost</u>	
Personnel Costs:	\$346,900	\$433,600	$(\$346,900/0.8)^{(b)}$
Materials & Supplies:	138,800	138,800	
Electric Power:	160,000	137,000	$(\$160,000/1.17)^{(c)}$
Total Annual Cost of 750-MTU- capacity storage pool	\$645,700	\$709,400	

B) Adjusted Cost of an Average
Capacity (595 MTU) Pool at a
Generic U.S. Location:

\$666,800 ~ \$670,000 $(709,400 \times .94)^{(d)}$

(a) Materials and supplies are estimated to be 40% of personnel costs (see Subsection 3.3).

(b) Duke Power's estimated personnel costs were divided by 0.8 to account for the fact that the southeast region's personnel costs were approximately 80% of the U.S. average (in 1988).

(c) Morris Operation's electricity costs were divided by 1.17 to account for the fact that Illinois' electric utility costs were approximately 117% of the U.S. average (in 1988).

(d) Capacity adjustment factor (see Table 3.3).

and additional electric power costs. The same geographic and capacity adjustments were made to the total cost in Table 3.4 as were made in Tables 3.2 and 3.3.

Table 3.5 shows the annual cost of operating a second additional inactive spent fuel pool. Additional personnel costs include a lead operations technician and an additional security guard for each shift (requiring four FTE lead operations technician positions and four FTE security guard positions) and the associated overhead (Wood et al. 1989). The only additional non-personnel costs included were for materials and supplies (estimated to be 40% of additional personnel costs) and additional electric power costs.^{(a)(b)} The same geographic and capacity adjustments to the total cost were made in Table 3.5 as were made in Tables 3.2 and 3.3.

3.6 ADDITIONAL ASSUMPTIONS

The overhead rate for personnel is assumed to be 47.5%, which is midway between the extremes of the range of overhead rates reported by utilities (40 to 55%).^{(a)(b)} The overhead rates reported by utilities seem low compared with other typical industrial overhead rates; however, the utility-reported rates were used in these estimates. Nuclear liability and property insurance was initially estimated to cost about \$400,000 per year per ISFSI (Wood et al. 1989). Cost figures are based on December 31, 1989, dollars.

Discussions with representatives of American Nuclear Insurers (ANI) revealed that typical annual cost to a nuclear utility site with an operating reactor is about \$800,000 for nuclear liability insurance and \$2,000,000 for property insurance, totaling \$2,800,000 per year. The best ANI estimate for the cost of similar coverage for a nonoperational site with spent fuel present (i.e., an ISFSI) would be from 10 to 25% of the total nuclear insurance cost for an operating reactor site, or from about \$280,000 to about \$700,000 per year. This range of insurance costs is still speculative, however, since ANI has not yet insured such a facility.^(c) Given the uncertainty, the initial estimated annual insurance cost of \$400,000 was retained for use in this study.

Only costs associated with long-term spent fuel storage (i.e., steady-state operation) are included. Costs associated with receiving and shipping spent fuel elements are excluded (e.g., additional manpower, equipment, etc., for either receiving/unloading or loading/shipping transport casks).

-
- (a) Internal communication, T. W. Wood to S. R. Rod, May 22, 1990. "Ops Cost After Shutdown," Pacific Northwest Laboratory, Richland, Washington.
 - (b) Personal communications with R. I. Smith, June 1-21, 1990. Pacific Northwest Laboratory, Richland, Washington.
 - (c) Personal communications with J. P. Marone, Senior Vice President and General Counsel, August 8, 1990. American Nuclear Insurers, Farmington, Connecticut.

Other costs not included in this analysis are

- Facility decommissioning costs, including the cost of final disposition of liquid and solid radioactive wastes currently accumulated on the site, for eventual disposal at decommissioning.
- Local, county, and state fees and taxes; notably, property taxes.
- Additional costs related to insurance, licensing, inspection, and regulatory compliance for additional pools.

4.0 REFERENCES

10 CFR 72. 1990. U.S. Nuclear Regulatory Commission. Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste. U.S. Code of Federal Regulations.

Ball, J. R. 1986. A Handbook for Quick Cost Estimates: A Method for Developing Quick Approximate Estimates of Costs for Generic Actions for Nuclear Power Plants. NUREG/CR-4568, ANL/EES-TM-297, Argonne National Laboratory, Argonne, Illinois.

Bureau of the Census. 1990. Statistical Abstract of the United States: 1990. 110th Edition, U. S. Department of Commerce, Washington, D.C.

Claiborne, E., F. Sciacca, G. Simion, and G. Baca. 1989. Generic Cost Estimates: Abstracts from Generic Studies for Use in Preparing Regulatory Impact Analyses. NUREG/CR-4627 Rev. 1, Science & Engineering Associates, Albuquerque, New Mexico.

General Electric Corporation (GE). 1990. Consolidated Safety Analysis Report for Momis Operation, March 1990 Update. NEDO-21326D4, USNRC Docket #70-1308, General Electric Corporation, Pittsburgh, Pennsylvania.

Hill, O. F., A. M. Platt, and J. V. Robinson. 1983. Nuclear Fact Book. PNL-4239 Edition 2, Pacific Northwest Laboratory, Richland, Washington.

Humphreys, K. K., L. L. Clark, M. R. Shay, S. M. Short, and D. L. Stiles. 1991. System Engineering Cost Analysis Capability Technical Reference Manual. PNL-7443, Vol.1, Pacific Northwest Laboratory, Richland, Washington.

McCartney, J. S., and R. B. Cairns. 1984. Cost Comparisons for On-Site Spent Fuel Storage Options. EPRI NP-3380, Electric Power Research Institute, Palo Alto, California.

U.S. Department of Energy (DOE). 1989. Spent Fuel Storage Requirements 1989-2020. DOE/RL-89-30, Richland Operations Office, Richland, Washington.

Wood, T. W., S. M. Short, M. G. Woodruff, M. K. Altenhofen, and C. A. MacKay. 1989. MRS Systems Study Task G Report: The Role and Functions of Surface Storage of Radioactive Material in the Federal Waste Management System. PNL-6876, Pacific Northwest Laboratory, Richland, Washington.

APPENDIX A

BACKGROUND SURVEY CONTACTS

APPENDIX A

BACKGROUND SURVEY CONTACTS

American Nuclear Insurers:	Joseph P. Marrone, Sr. VP & General Counsel Richard Jones
Baltimore Gas & Electric:	Robert H. Beall
Battelle Memorial Institute:	V. Pasupathi Joseph W. Ray
Pacific Northwest Laboratory:	James M. Creer Kenneth K. Humphreys Richard I. Smith Steven M. Short Thomas W. Wood
Duke Power Company:	Robert Rasmussen
Electric Power Research Institute:	Ray Lambert
General Electric Corporation, Morris Operation:	T. E. Ingels, Plant Manager James Kesman, O&M Manager
Pacific Gas & Electric Company, Humbolt Bay Power Station:	George Sarkisian
U.S. Nuclear Regulatory Commission:	Richard Bangart Lewis Bykoski Peter Ericson Timothy Johnson Timothy Margolis Daniel Martin John Roberts John Surmeier Lena Thomas Robert Wood
Virginia Power Company:	Marvin Smith

Westinghouse Electric Corporation,
West Valley Nuclear Services Company:
Fuel Program:
Cost Accounting:

Bernard Conners, Manager
Todd Cotter
Bruce Wiesen

APPENDIX B

MORRIS OPERATION ORGANIZATION CHART

Morris Operation Organization Chart^(a)

(a) "Ops Case after Shutdown." Internal communication from T. W. Wood to S. R. Rod, May 22, 1990. Pacific Northwest Laboratory, Richland, Washington.

DISTRIBUTION

No. of Copies

OFFSITE

- 12 DOE/Office of Scientific and
Technical Information

- 14 Office of Civilian Radioactive
Waste Management
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20545
ATTN: J. Carlson, RW-40
R. Blaney, RW-4
A. Brownstein, RW-40
W. Danker, RW-4
S. Gomborg, RW-322
H. Hale, RW-30
T. Isaacs, RW-43
C. Kouts, RW-40
W. Lemeschewsky, RW-30
R. Milner, RW-40
T. Pollog, RW-40
J. Saltzman, RW-5
D. Shelor, RW-30
J. Williams, RW-40

- 3 Yucca Mountain Project Office
U.S. Department of Energy
P.O. Box 98518
Las Vegas, NV 89183-8518
ATTN: M. Cloninger
C. Gertz
G. Rodriguez

- 17 Battelle Washington Operations
370 L'Enfant Promenade
Suite 900
Washington, DC 20024-2115
ATTN: C. MacKay
J. Strahl
S. Rod (15)

No. of Copies

- 2 Sandia National Laboratory
Division 6311
Albuquerque, NM 87105
ATTN: A. Dennis
G. Hertel

- 4 Roy F. Weston, Inc.
955 L'Enfant Plaza, SW
Washington, DC 20024
ATTN: N. Dayem
J. DiNunno
M. Conroy
J. Lilly

- 3 E. R. Johnson & Associates, Inc.
10461 White Granite Dr.
Suite 204
Oakton, VA 22124
ATTN: B. Cole
E. Johnson
N. McLeod

- 2 Lawrence Livermore National
Laboratory
P.O. Box 806
Livermore, CA 94550
ATTN: L. Ballou
M. Revelli

- JK Associates
1001 Spring Street
Suite 406
Silver Spring, MD 20910
ATTN: T. Cotton

No. of
Copies

- 2 Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37830
ATTN: D. Joy
W. McClain
- 2 DOE Field Office, Richland

D. C. Langstaff
J. J. Sutey

No. of
Copies

- 15 Pacific Northwest Laboratory

S. Q. Bennett
G. J. Konzek
M. R. Kreiter
R. W. McKee
M. R. Shay
S. R. Short
R. I. Smith
T. W. Wood
M. G. Woodruff
Publishing Coordination
Technical Report Files (5)