DOE/EIS-0015
VOLUME 2 OF 5

FINAL ENVIRONMENTAL IMPACT STATEMENT U. S. SPENT FUEL POLICY

Storage of U.S. Spent Power Reactor Fuel

VOLUME 2

MAY 1980

U.S. Department of Energy
Assistant Secretary for Nuclear Energy

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Available from:

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price: Printed Copy: $11.75
Microfiche: $ 3.00

FOREWORD

Spent fuel removed from a nuclear power reactor contains unfissioned nuclear fuel together with radioactive wastes. On April 7, 1977, President Carter announced that the U.S. would indefinitely defer reprocessing of spent fuel to recover the unfissioned fuel while the U.S. and other countries evaluate alternative fuel cycles and processes which may reduce risks of nuclear weapons proliferation. Eventually, the spent fuel will either be declared to be entirely waste and provision made for its disposal, or it will be reprocessed to separate the wastes from the unfissioned nuclear fuel which may then be recycled and the waste disposed of separately. However, pending future decisions as to its ultimate disposition, the spent fuel discharged from U.S. power reactors must be stored, protected and safeguarded.

C In October 1977, a Presidential announcement on the interim management of spent fuel was made. Under this policy, the Federal Government would offer to take title to and provide interim storage for spent fuel from U.S. power reactors. In August 1978, a draft generic environmental statement (DOE/EIS-0015-D) was issued to provide environmental input into decisions on whether, and if so, how this Spent Fuel Storage Policy should be implemented. Notice of availability of this document was published in the Federal Register on September 6, 1978 and public comments were solicited. As a result of some of the comments received, a supplement to the environmental statement was issued in December 1978 (DOE/EIS-0015-DS). This supplement included an alternative of expanded storage of fuel in new basins at reactor sites to minimize fuel transshipments.

The closing date for comments on the EIS, as published in the Federal Register, was February 15, 1979. A total of 78 comment letters (some with supplements) were received on the environmental statement and its supplement, on a companion draft environmental impact statement on storage of foreign spent reactor fuel (DOE/EIS-0040-D), and on establishing the charge for spent fuel storage (DOE/EIS-0041-D). Major comments from these letters are categorized and published in Volume 5 of this final EIS (DOE/EIS-0015).

Pertinent major comments received on draft statements DOE/EIS-0015-D, DOE/EIS-0015-DS, DOE/EIS-0040-D, and DOE/EIS-0041-D are now incorporated into five volumes of the Final Environmental Impact Statement (EIS), U.S. Spent Fuel Storage Policy, DOE/EIS-0015. These five volumes consist of

C Volume 1: Executive Summary

Volume 2: Storage of U.S. Spent Power Reactor Fuel

Volume 3: Storage of Foreign Spent Power Reactor Fuel

Volume 4: Charge for Spent Fuel Storage

Volume 5: Comment Letters on Draft Statements and Major Comments With DOE Responses

Changes from the draft statement are indicated by vertical lines in the left margin of the pages. Where a change was the result of a major comment, each comment is identified with a line delineating the changed material and a number and a letter corresponding to its designation in Volume 5, Final Environmental Impact Statement, Comment Letters on Draft Statement and Major Comments With DOE Responses. If the change is the result of an error in the draft statement, it is identified with the letter "E," or if the change is made to clarify or expand on the draft statement, it is identified with the letter "C."

This final environmental impact statement evaluates the potential environmental impacts associated with various options for governmental involvement in the interim storage of domestic spent fuel, including the alternative of no Federal role other than the regulatory sphere. In assessing these impacts, the issues associated with centralized versus decentralized storage and the issues associated with the degree of Federal management control over spent fuel are analyzed.

1-a The Department of Energy's (DOE) preferred alternative for this action is to implement the Spent Fuel Storage Policy and to take title to U.S. spent fuel offered to the U.S. Government. In general, utilities can and should provide their own spent fuel storage capability but in some isolated cases this may not be practicable due to technical or regulatory reasons. Furthermore, it is desirable for U.S. utilities to maintain reserve capacity for storing the full reactor core, if its discharge becomes necessary. This would avoid potential extended reactor outages and the resulting economic penalties to the energy user from purchasing electric power produced from potentially more costly fossil fuels.

To permit an analysis of the impacts of various options for interim storage, the assumption is made in this volume that permanent disposition of spent fuel, either to waste disposal or to a reprocessing plant, begins at the earliest in the year 1985.

C The effects of delayed disposition of the spent fuel for various periods up to the year 2000 are included in this volume. Delays in the opening of the first disposition facility beyond the time frame originally analyzed in this EIS is a possibility. Between the time the draft EIS documents were written and the final EIS was completed, DOE recognized that the first disposition facility might not be in operation until the mid to late 1990s. As a result, DOE decided to prepare an appendix (Appendix E) to this volume to show the environmental effects associated with the interim storage of U.S. power reactor fuel in ISFS facilities with the first disposition facility startup in the year 2010. The appendix compares the effects of the delay in startup of the facility if the U.S. Spent Fuel Storage Policy is implemented or is not implemented. The effects on the amount of ISFS storage requirements are also given to the year 2040. This volume does
6-a not address the environmental impacts of the options for the ultimate disposition of spent fuel. The draft environmental impact statement, <u>Management of Commercially Generated Radioactive Waste</u> (DOE/EIS-0046-D) analyzes the options for disposal of spent fuel as high-level waste and waste from fuel cycles that included reprocessing. DOE/EIS-0046-D included analysis of alternative interim storage requirements for the various disposal options.

C ISFS facilities are assumed to be available in the fiscal year 1983. It is no longer practical to complete a newly constructed ISFS by the year 1983. The earliest a newly constructed ISFS could be made available is in the late 1980s if immediate funding is available. Therefore, DOE is studying the purchase or lease of existing privately owned facilities, or possible use of existing government facilities, as options to provide storage capacity in the 1983 time frame. In DOE testimony to the U.S. Senate Committee on Environment and Public Works, on September 13, 1979, it was stated that DOE has looked at the spent fuel pools at AGNS/Barnwell, GE/Morris, and NFS/West Valley, since these pools exist and could provide needed space in the time frame necessary.

GE/Morris is currently receiving and storing spent fuel. NFS/West Valley is not receiving spent fuel. AGNS/Barnwell facility is complete but has not been licensed to receive spent fuel. Capacity increases over the current limit at each of the three facilities are considered possible. Existing U.S. Government facilities that could be modified and used to store spent fuel have been identified in <u>Spent Fuel Program Preliminary Technical Assessment of Existing Facilities for AFR Storage Capability</u>, DOE/SR/10007-1-Rev 1 (September 1979).

Included in this final EIS on the Spent Fuel Storage Policy are an EIS on storage of foreign spent power reactor fuel in the U.S. (Volume 3) and an EIS on the spent fuel storage/disposal charge methodology (Volume 4). The foreign spent fuel EIS is concerned with the environmental impact of receipt of foreign spent fuel for interim storage and possible ultimate disposal by the U.S. Government. The EIS on spent fuel charge methodology is concerned with the environmental impact of alternative approaches for the establishment of a charge for storage and disposal of spent fuel.

1-b If a decision is made to implement the Spent Fuel Storage
1-c Policy, an away-from-reactor spent fuel storage facilities EIS
(AFR EIS) will be prepared to provide the environmental input into
the selection of facilities to meet the demand for spent fuel
storage. The demand for spent fuel storage will be developed by
1-c using the latest available data as supplied by utilities concerning
their plans for expansion, compaction, transshipments, and the
expected quantities of spent fuel discharges. The environmental
effects associated with the construction and/or operation of the
facilities and the transportation effects associated with the
available options will be evaluated.

As proposed in the Spent Nuclear Fuel Act of 1979 (see Appendix B of Volume 1), ISFS facilities for interim storage of spent fuel will be licensed by the Nuclear Regulatory Commission (NRC). The NRC licensing process will provide additional public input.

Other related environmental reviews which provided input into this volume include: <u>Final Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel</u> (NUREG 0575) and <u>Light Water Reactor Fuel Reprocessing and Recycling</u> (ERDA-77-75).

The support document, <u>Analytical Methodology and Facility and Environmental Description — Spent Fuel Policy</u> (DOE-ET-0054) contains additional data that may be of interest to some reviewers and it is referenced in this volume.

A Glossary of Terms and Abbreviations is included as
C Appendix F.

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III. Alternatives and Their Environmental Effects (Contd)

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I. SUMMARY

In October 1977, the Department of Energy (DOE) announced a Spent Fuel Storage Policy for nuclear power reactors. Under this policy, as approved by the President, U.S. utilities will be given the opportunity to deliver spent fuel to U.S. Government custody in exchange for payment of a fee. The U.S. Government would also be prepared to accept a limited amount of spent fuel from foreign sources when such action would contribute to meeting nonproliferation goals. Under the new policy, spent fuel transferred to the U.S. Government will be delivered — at user expense — to a U.S. Government-approved storage site.

A bill was submitted to Congress in March 1979, to implement the Spent Fuel Storage Policy. This bill, known as the "Spent Nuclear Fuel Act of 1979" (see Volume 1, Appendix B) would authorize the Secretary of Energy to acquire or construct one or more away-from-reactor storage facilities. These storage facilities would be licensed by the Nuclear Regulatory Commission. The Secretary would be authorized to take title to and provide interim storage and ultimate disposal for domestic spent fuel and limited amounts of foreign spent fuel. Nondiscriminatory, prepaid charges for storage would cover all government costs of storage and ultimate disposal. Provisions are made to refund a portion of the charges in the eventuality that spent fuel were to be reprocessed. A revolving fund would be established to finance activities and functions associated with away-from-reactor interim storage and ultimate disposal facilities. The Secretary of Energy would have the authority to sell up to $300,000,000 worth of bonds to the Treasury to assist in financing these activities.

In this volume of the environmental impact statement, the environmental impacts of implementing or not implementing the policy for interim storage of U.S. spent fuel are analyzed. Because the details of the implementation of the policy have not yet been developed, the statement is prepared on a generic, rather than a facility-specific basis.

Description of Alternatives

When the draft version of this EIS[1] was prepared in the latter part of the year 1977 and early 1978, the national objective was to open the first geologic repository in the year 1985. Environmental effects of interim storage of spent reactor fuels were determined for the disposition facility* operation beginning

* The generic term disposition facility is used in this volume of the EIS to denote disposal of spent fuel as waste in a geologic repository or to denote reprocessing and disposal of the reprocessing waste in a geologic repository. (Reprocessing for the U.S. has been indefinitely suspended and is not the current U.S. policy.) Disposition activities are not analyzed in this volume.

C in the year 1985 or 1995, and ISFS facility effects were
determined through the year 2000 to ensure that the range of
actions was covered by the EIS. The alternatives analyzed were
Alternative 1 — Policy Implemented and Alternative 2 — Policy
6-b Not Implemented. Between the time the draft document was
published and this final EIS was complete, DOE recognized that
the first repository might not be in operation until the years
from 1997 to 2006. To demonstrate the effects of a delayed
repository opening beyond the year 1995, an appendix was prepared
for this EIS (Appendix E) to show the environmental effects with
the first repository startup in the year 2010.

The analyses used to show the environmental effect comparison of disposition facility startup in the year 2010 were selected to parallel Alternatives 1 and 2 in the draft EIS. Although not true decision alternatives, these analyses have been labeled Alternative 3 — Policy Implemented and Alternative 4 — Policy Not Implemented. These alternative numbers were selected to differentiate between the alternatives which consider earlier startup dates for the disposition facility (Alternatives 1 and 2). Alternatives 3 and 4 (disposition facility startup in the year 2010) use an updated forecast of fuel flow and interim storage requirements than Alternatives 1 and 2, so Alternatives 1 and 2 cannot be directly compared to Alternatives 3 and 4. The comparison of environmental effects to be used in the decision to implement or not to implement the policy should be based on comparison of alternatives for the same disposition facility startup date.

Two basic alternatives are considered in this statement. In the first alternative (Alternative 1 for 1985 or 1995 disposition facility startup, and Alternative 3 for a year 2010 startup), the Spent Fuel Storage Policy, in which the U.S. Government accepts title to the spent fuel, is assumed to be implemented. In the second alternative (Alternative 2 for 1985 or 1995 disposition facility startup, and Alternative 4 for a year 2010 startup), the Spent Fuel Storage Policy is assumed not to be implemented.

Two options associated with Alternatives 1 and 3 are examined
in this volume: A) centralized storage in large independent spent
fuel storage (ISFS) facilities owned or operated by the U.S.
Government and B) decentralized storage in reactor basins and
small government or privately owned ISFS facilities. In these
options it is assumed that industry utilizes compaction (densi-
C fication) and in Alternative 1 transshipments are used to limit
the number of ISFS facilities that will be required. These options
span the possible range of fuel management under the new policy.
In both options, the spent fuel is expected to be stored for five
years or longer in the reactor basins or in existing away-from-
reactor basins unless emergency shipments are required for
continued reactor operation. These options are summarized in
Table I-1.

TABLE I-1

Summary of Parameters Involved in Alternatives/Options Analyzed

Alternative/Option	1A	1B-1	1B-2	2A	2B	3A	3B	4A	4B
U. S. Spent Fuel Policy is Implemented and U. S. Government Takes Title to Spent Fuel	●	●	●[a]			●	●		
U. S. Spent Fuel Policy is Not Implemented				●	●			●	●
Year of Disposition Facility Startup	1985 1995	1985 1995	1985 1995	1985 1995	1985 1995	2010	2010	2010	2010
Full-Core Reserve Status									
• FCR Regained, year (1985 Disposition Facility Startup)	1986	1986	1991	1991	1986				
• FCR Regained, year (1995 Disposition Facility Startup)	1986	1986	After 2000	After 2000	1986				
• FCR Regained, year (2010 Disposition Facility Startup)						1983	1983	1983	1983
Basin Compaction Utilized	●	●	●	●	●	●	●	●	●
Transshipments Between Reactors, MTU									
• 1985 Disposition Facility Startup	7100	7100	7100	7100	650				
• 1995 Disposition Facility Startup[b]	7100	7100	7200	7200	650				
• 2010 Disposition Facility Startup						none	none	none	none
Centralized Storage Utilized	●					●			
Decentralized Storage Utilized		●	●	●	●		●	●	●
ISFS Facilities Utilized	●	●	●	●		●	●	●	
ARB Facilities Utilized					●				●
U. S. Government Builds ISFS Facilities	●	●	●			●	●		
Private Industry Builds ISFS Facilities		●	●	●				●	
Private Industry Builds Stand-Alone ARBs					●				●
Interim Storage Capacity Required in ISFSs and ARBs, MTU									
• 1985 Disposition Facility Startup	5400	5400	500	500	5400				
• 1995 Disposition Facility Startup[b]	51500	51500	24000	24000	52500				
• 2010 Disposition Facility Startup						91200	91200	91200	91200
Number of Interim Storage Facilities Needed									
• 1985 Disposition Facility Startup	1	1	1	1	45				
• 1995 Disposition Facility Startup[b]	1	9	4	4	93				
• 2010 Disposition Facility Startup						6	16	16	269

a. Same parameters whether U. S. Government owned or private utility owned

b. Delay of disposition facility startup beyond the year 2000 is possible and is discussed in Section III and Appendix E.

In Alternatives 1A and 3A (centralized storage), irradiated reactor fuel is assumed to be shipped to an ISFS facility starting in the year 1983. In Alternative 1A, a disposition facility is assumed to become available in the year 1985 (in the year 2010 in Alternative 3A). This facility may be for disposal of spent fuel as waste or, if recycling is approved, wastes from a reprocessing plant. The ISFS facility is assumed to be located separately from the disposition facility so that the analysis will conservatively estimate environmental effects. This is not meant to preclude possible collocation of the facilities, which would cause less environmental impact because less transportation is required. The report to the President by the Interagency Review Group on Nuclear Waste Management[2] indicates that initial operation of the first geologic repository for high-level waste (spent fuel or reprocessing waste) is expected between the years 1988 and 1995. The IRG Report[3] was reissued in March 1979, after extensive public review. The conclusion on the earliest date for operation of a geologic repository for high-level waste had not, however, changed. The March IRG Report did indicate, however, that the range of dates did not reflect the IRG's estimate of "political or unforeseen technical difficulties," but "some members of the IRG believe that these additional uncertainties actually cause the range of estimated dates of opening the first repository." (DOE now recognizes that the first repository might not start up until the years from 1997 to 2006 and this final EIS has been amended to include analyses of a startup date of the year 2010 to cover the range of environmental effects.)

During the first four years of operation, the disposition facility operates at partial capacity, and spent fuel is shipped to both the ISFS facility and to the disposition facility. By the year 1986 (Alternative 1A) or the year 1983 (Alternative 3A), spent fuel shipments from the reactors to the ISFS facility and the disposition facility would have reduced inventories at individual reactor discharge basins sufficiently to permit full-core discharge from the reactor. DOE considers operation of reactor discharge basins with full-core reserve highly desirable from an operational flexibility and power supply reliability standpoint.

If a disposition facility is started up in the year 1985, it should reach full capacity operation in the year 1988, and spent fuel will then be shipped directly from the reactor discharge basins to the disposition facility and no longer to ISFS facilities. Approximately 5400 MTU of spent fuel will be shipped to the ISFS facilities between the years 1983 and 1988. Spent fuel movement and timing under Alternative 1A, which assumes this scenario, is given in Table I-2 for startup of the disposition facility in the year 1985.

TABLE I-2

Spent Fuel Shipments — Centralized Storage — Policy Implemented (Alternative 1A) Disposition Facility Startup, 1985

	ISFS Basins			*Disposition Facility*		
	Fuel Shipments, MTU			*Fuel Shipments, MTU*		
Year	*Reactor to ISFS Basin*	*ISFS Basin to Disposition Facility*	*Inventory, MTU*	*Reactor to Disposition Facility*	*ISFS Basin to Disposition Facility*	*Inventory, MTU*
1978	-	-	0	-	-	0
1979	-	-	0	-	-	0
1980	-	-	0	-	-	0
1981	-	-	0	-	-	0
1982	-	-	0	-	-	0
1983	970	-	970	-	-	0
1984	1580	-	2550	-	-	0
1985	1602	-	4152	100	-	100
1986	468	-	4620	1600	-	1700
1987	736	-	5356	1600	-	3300
1988	-	-	5356	3155	-	6455
1989	-	-	5356	3368	-	9823
1990	-	-	5356	3760	-	13583
1991	-	530	4826	4168	530	18281
1992	-	1410	3416	4453	1410	24144
1993	-	1300	2116	4776	1300	30220
1994	-	1300	816	5026	1300	36546
1995	-	816	0	5481	816	42843
1996	-	-	0	5478	-	48321
1997	-	-	0	5505	-	53826
1998	-	-	0	5965	-	59791
1999	-	-	0	6018	-	65809
2000	-	-	0	6406	-	72215

Potential environmental impacts under Alternative 1A are also assessed for delayed startup of the disposition facility. ISFS facility storage capacity requirements increase sharply from about 5400 MTU if the disposition facility is delayed (ISFS facility requirements increase to about 24,000, 52,000, or 85,000 MTU of spent fuel if the facility is delayed 5, 10, or 15 years, respectively). The required capacity is assumed to be added to the ISFS facilities as needed. Even with a delayed disposition facility, spent fuel shipments from the reactors to ISFS facilities will have reduced inventories at individual reactor basins sufficiently to permit full-core discharge by the year 1986. Detailed calculations of environmental effects of delayed startup of the disposition facility are performed for Alternative 1A, assuming a ten-year delay (1995 startup).

C Alternative 3A assumes a similar scenario of storage of spent fuel in centralized ISFS facilities until disposition facilities start up. This alternative assumes that the disposition facility startup is delayed until the year 2010. It is also based on DOE's current estimates of fuel flows expected to require away-from-reactor storage. In this alternative, full capacity operation of the disposition facility is expected to occur in the year 2014. This results in approximately 91,200 MTU of storage at ISFS facilities. Table I-3 shows the spent fuel movement and timing under Alternative 3A for startup of the disposition facility in the year 2010.

In Option B (decentralized storage), storage requirements are met by construction of small government or private ISFS facilities. C For Alternative 1B, two suboptions were examined. The suboptions include the assumption that 1) ISFS facility capacity be provided in the year 1983, that disposition facility capacity be provided by the year 1985, and that inventories at individual reactor discharge basins be reduced sufficiently to permit full-core discharge from reactor; and 2) ISFS facility capacity be provided in the year 1983, that disposition facility capacity be provided by the year 1985, and that the inventories at individual reactor discharge basins be limited to the reserve capacity necessary for one yearly reactor discharge until the disposition facility capacity is large enough to allow these basins to regain full-core reserve. The first of these two suboptions is identified as Alternative 1B-1, and the environmental effects are essentially the same as Alternative 1A. The second suboption is identified as Alternative 1B-2 and is described in the next several paragraphs.

In Alternative 1B-2 (decentralized storage), most irradiated reactor fuel is retained in the reactor storage facility, and reserve basin capacity equivalent to one scheduled annual discharge is maintained. Additional storage requirements are met by construction of small government or private ISFS facilities. In the

TABLE I-3

C

Domestic Spent Fuel Shipments — Centralized Storage (Alternative 3A) or Decentralized Storage (Alternative 3B) — Policy Implemented and Decentralized Storage in Private ISFS Facilities (Alternative 4A) — Policy Not Implemented

Year	*ISFS Basins Fuel Shipments, MTU*	*ISFS Basin Inventory, MTU*	*Disposition Facility Fuel Shipments, MTU*		*Disposition Facility Inventory, MTU*
	Reactor to ISFS Basin		*Reactor to Disposition Facility*	*ISFS Basin to Disposition Facility*	
1983	400	400			
1984	200	600			
1985	200	800			
1986	300	1100			
1987	400	1500			
1988	500	2000			
1989	600	2600			
1990	700	3300			
1991	900	4200			
1992	1300	5500			
1993	1600	7100			
1994	1700	8800			
1995	2100	10900			
1996	2400	13300			
1997	2800	16100			
1998	3100	19200			
1999	3500	22700			
2000	3600	26300			
2001	4000	30300			
2002	4200	34500			
2003	4000	38500			
2004	6300	44800			
2005	4700	49500			
2006	5600	55100			
2007	5400	60500			
2008	7300	67800			
2009	4700	72500			
2010	6400	78900	100		100
2011	5100	84000	1600		1700
2012	5400	89400	1600		3300
2013	1800	91200	5200		8500
2014	0	90200	7500	1000	17000
2015		89400	7800	800	25600
2016		87600	8300	1800	35700
2017		86300	8900	1300	45900
2018		80200	9200	6100	61200
2019		71576	9700	8624	79524
2020		63011	10200	8565	98289
2021		54746	10500	8265	117054
2022		47081	11100	7665	135819
2023		39816	11500	7265	154584
2024		32951	11900	6865	173349
2025		26586	12400	6365	192114
2026		20621	12800	5965	210879
2027		15156	13300	5465	229644
2028		10091	13700	5065	248409
2029		5626	14200	4465	267074
2030		1500	14600	4126	285800
2031		0	15100	1500	302400

year 1985, a disposition facility becomes available on the same basis as in Alternative 1A. By the year 1991, five years later than in Alternative 1A or 1B-1, spent fuel shipments from the reactors to the ISFS facility and the disposition facility will reduce inventories at individual reactor discharge basins sufficiently to permit full-core discharge. Approximately 500 MTU of spent fuel is shipped to government or private ISFS facilities between the years 1983 and 1986.

Potential environmental impacts from Alternative 1B-2 are also assessed for delayed startup of the disposition facility. Again, the ISFS facility requirements increase sharply from about 500 MTU if the disposition facility is delayed (ISFS facility requirements are about 8,000, 24,000, or 52,000 MTU of spent fuel if the facility is delayed 5, 10, and 15 years, respectively). These increased requirements are not as great as Alternatives 1A or 1B-1 because larger inventories are maintained in reactor discharge basins in Alternative 1B-2.

In Alternative 1B, the government or private ISFS facilities are assumed to begin operation in the year 1983 with capacity added later, as needed. Spent fuel shipments are accelerated after the disposition facility becomes available, but, for delayed startup of ten years or greater, inventories at individual reactors will not be reduced sufficiently to permit full-core discharge until after the year 2000. Detailed calculations of environmental effects of delayed startup of the disposition facility are performed, assuming a ten-year delay (1995 startup). Delay of disposition facility beyond the year 2000 is possible and is treated qualitatively. It should be emphasized that the assumption in Alternative 1B-2 regarding reactor discharge basin spare capacity equivalent to one scheduled annual discharge was made for illustrative purposes only, in order to maximize the differences in environmental effects between Alternatives 1A and 1B-1 and Alternative 1B-2. Operation of reactor discharge basins at less than full-core reserve capacity is undesirable, as it will reduce operational flexibility and may lead to prolonged shutdowns due to lack of readily available storage space. The differences in environmental effects between Alternatives 1A and 1B-1 and Alternative 1B-2 are very slight, as discussed later in this section.

In Alternative 3B (decentralized storage, with the disposition facility delayed until the year 2010), storage requirements are met by construction of small government ISFS facilities. It is assumed that ISFS facility capacity will be provided starting in the year 1983, that inventories at individual reactor discharge basins will be reduced sufficiently to permit full-core discharge from reactors, and that disposition facility capacity will be provided in the year 2010. Approximately 91,200 MTU of spent fuel will be shipped to these ISFS facilities until the disposition facility reaches full-scale operation in the year 2014. This is the same spent fuel movement schedule as used in Alternative 3A.

The alternative of not implementing the storage policy is also examined. In Alternatives 2 and 4, the "Policy Not Implemented"* cases, the U.S. Government is assumed to take no action to assist private industry in resolving the uncertainties associated with interim storage of spent nuclear fuel. These alternatives have two options that are analyzed in this volume. In both of these options, private industry is assumed to use compaction to limit the number of privately owned basins that will be required.

In Alternative 2A, the accumulation of spent fuel in reactor basins is assumed to be limited to maintain capability for one annual discharge until full-scale operation of a disposition facility allows full-core reserve to be regained in reactor discharge basins. This option utilizes transshipping of spent fuel between reactors to limit the amount of new basin capacity needed. The disposition facility is assumed to be available on the same schedule as in Alternative 1 ("Policy Implemented Case"). New ISFS facilities are built as required by private industry. Spent fuel movement and inventories under Alternative 2A are identical to those in Alternative 1B-2. Facility requirements and potential environmental effects are determined for the same activities as in Alternative 1B-2 and are identical to those determined for that option.

In Alternative 4A, the accumulation of spent fuel in reactor basins will be limited to maintain full-core reserve capacity in reactor discharge basins. The disposition facility is assumed to be available on the same schedule (beginning in the year 2010) as Alternative 3 (Policy Implemented). New ISFS facilities are built as required by private industry. Spent fuel movements and inventories under Alternative 4A are the same as in Alternative 3A.

In Alternatives 2B and 4B, small, stand-alone basins are privately constructed at existing reactor sites for storage of spent fuel from the reactor discharge basins of nearby reactors until final disposition. These facilities are called at-reactor basin (ARB) facilities. The major differences between these two alternatives are the fuel flows assumed and the startup dates of the initial disposition facility. Fuel flow and disposition facility differences are those identified earlier in this section for Alternative 3A. In Alternative 2B (but not in Alternative 4B),

* "Policy Not Implemented" as used in this volume is synonymous with the government not taking title to the spent nuclear fuel.

transshipments of spent fuel between reactor basins are permitted, but are limited to shipments needed to prevent reactor shutdown before the availability of at-reactor basins (ARBs) and are not
C allowed after ARBs become available in the year 1983. Full-core reserve is regained in Alternatives 2B and 4B as soon as ARBs and the disposition facility become available.

Description of Generic Facilities

The generic ISFS or ARB facilities in this volume are assumed to consist of a set of modular water-filled basins. The maximum capacity of a single centralized ISFS facility is assumed to be 18,000 MTU of spent fuel. For the decentralized facilities, the maximum capacity is assumed to be 6000 MTU. ARB facilities are
C much smaller, normally 500 to 2000 MTU. The storage basins are stainless steel-lined concrete structures. The facility is designed to receive, handle, decontaminate, and reship spent fuel casks; to remove irradiated fuel from casks; to place the fuel in the basins; and to cool and control the quality of the water. The facility is also designed to remove spent fuel from the storage basins, load the spent fuel into shipping casks, decontaminate loaded casks, and ship spent fuel. Modular construction allows facility expansion with a minimum of additional support facilities and services.

Because many areas of the country are suitable for the construction of ISFS facilities, a generic site environment was selected in this volume for quantitatively assessing the environmental effects of constructing and operating these facilities.
1-b If the decision is made to implement the Spent Fuel Storage Policy, an away-from-reactor spent fuel storage facilities EIS (AFR EIS) will be prepared to provide environmental input into selection of the facilities for use in storing spent fuel accepted by DOE. Further site-specific environmental review will be required by NRC in connection with the licensing process.

Transportation

Transportation of spent fuel and waste involves use of massive, heavily shielded shipping casks transported both by truck and rail. About ten times more fuel can be shipped in a rail cask than in a truck. However, truck shipments normally require less turnaround time than rail shipments.

9-b In this EIS, the U.S. industry is assumed to fabricate sufficient casks and other transportation equipment after a firm implementation plan is established for storage and disposal of spent fuel.

For the transportation portions of this volume, 70% by weight of the U.S. spent fuel shipped from reactors is assumed C to be shipped by rail and the remainder by truck up to the year 2000. After the year 2000, it is assumed that 90% of the spent fuel is shipped by rail and the remainder by truck. In this volume, it is assumed that only truck casks are used to transfer 8-e spent fuel from reactor discharge basins to nearby at-reactor basins. Some future shipments in casks designed for rail transport may be made by barge, but the environmental effects of barge shipments will be about the same as rail transport.

Environmental Effects

C For each alternative considered in this EIS, some resources will be consumed; and small amounts of radioactivity will be released to the environment. The work force will be exposed to C limited amounts of radiation and will experience occupational accidents at rates comparable to those in similar industries. C The environmental effects of the alternatives will be limited by engineered systems, administrative controls, and monitoring programs. The environmental effects believed to be of greatest significance are given in Table I-4 for Alternatives 1 and 2, and in Table I-5 for Alternatives 3 and 4. Use of natural resources, release of thermal and nonradioactive effluents, and secondary effects on biota, are judged to have very minor impact and are C not included in Tables I-4 and I-5. Scenarios which assume that the disposition facility is delayed require increased energy and materials because of increased construction and operation of ISFS and ARB facilities.

The population dose commitments from environmental release of radioactivity determined for local [within 80 km (50 mi) of the facility], U.S., and the world populations are given in this report. The radiation dose commitments determined for the world C population are shown in Tables I-4 and I-5. Effects of long-lived nuclides in the 100-year period after the end of the study are included to provide an assessment of effects of persistent nuclides.

C For the alternatives which consider 1985 and 1995 disposition facility startups (Alternatives 1 and 2), world population dose commitments range from 1000 man-rem in Alternative 1A with disposition beginning in 1985 to 30,000 man-rem if fuel disposition is 7-a delayed until the year 1995 and ARBs are used. About half of these doses are received by the population within 80 km (50 mi) of facilities. To place these dose commitments in perspective, they are a very small fraction of the exposure from natural radiation sources in the same period [about 200,000,000,000 man-rem to the world population and 30,000,000 man-rem to the 80-km (50-mi) radius population].

TABLE I-4

Summary of Environmental Effects — Alternatives 1 and 2

Effects	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1)*[a] *– Policy Implemented* — *Disposition Facility Startup* *1985*	*1995*[b]	*Decentralized Storage with Discharge Capabilities - Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)* — *Disposition Facility Startup* *1985*	*1995*[b]	*Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)* — *Disposition Facility Startup* *1985*	*1995*[b]
Energy Resources						
Propane, m^3	5.9×10^2	2.7×10^3	1.7×10^2	1.8×10^3	7.7×10^3	1.6×10^4
Diesel fuel, m^3	1.7×10^5	2.2×10^5	1.7×10^5	2.0×10^5	3.1×10^5	4.8×10^5
Gasoline, m^3	1.0×10^4	4.7×10^4	3.0×10^3	3.0×10^4	1.4×10^5	2.8×10^5
Electricity, MW-yr	6.5×10^1	1.0×10^3	8.2×10^0	5.0×10^2	1.8×10^2	1.4×10^3
Coal, tonne	4.0×10^5	6.2×10^6	5.4×10^4	3.0×10^6	1.2×10^6	7.6×10^6
E | Manpower, man-hour	4.5×10^7	8.5×10^7	3.9×10^7	7.6×10^7	1.1×10^8	1.9×10^8
Radiation Dose Commitment, man-rem						
Worldwide population[c]	1×10^3	2×10^4	3×10^2	9×10^3	4×10^3	3×10^4
Workforce	1×10^3	5×10^3[d]	8×10^2	4×10^3	6×10^3	3×10^4
Health Effects[e]						
Worldwide population	1	10	1	6	2	13
Workforce	1	4[f]	1	3	4	19
7-j | Occupation Accidents (nonradiological fatalities)[g]	11	14[h]	11	14	23	42

a. The resource commitments for Alternative 1B-1 are similar to those shown for Alternative 1A but not exactly the same. The differences are small. Impacts are same whether provided by U.S. or utilities if policy is not implemented.

b. Delay of disposition facility startup beyond the year 2000 is possible and is discussed in Section III and Appendix E of this volume.

7-a | *c.* Whole body dose during the operating period plus the next 100 years. (For comparison, the equivalent dose to the world population from natural radiation sources over the same period is about 2×10^{11} man-rem. This natural radiation dose will result in 120 million health effects.)

d. For Alternative 1B-1 the work force dose commitment is 8×10^3 man-rem.

e. Serious genetic and somatic health effects were calculated from radiation doses, assuming a linear dose-health effect relation. EPA dose-effect factors were used.

f. For Alternative 1B-1, the work force health effects are 6.

7-j | *g.* Includes construction deaths.

| *h.* For Alternative 1B-1, the fatalities from occupational accidents are 17.

TABLE I-5

Summary of Environmental Effects — Alternatives 3 and 4 for 2010 Startup of Disposition Facility

	Policy Implemented		*Policy Not Implemented*	
	Centralized Storage (Alternative 3A)	*Decentralized Storage (Alternative 3B)*	*Decentralized Storage (Alternative 4A)*	*Storage in ARBs (Alternative 4B)*
World Population, Whole Body Dose Commitment, man-rem	46,200	46,200	46,200	85,100
Occupational Exposure, man-rem	9,600	15,300	15,300	92,400
World Health Effects[a]	34	38	38	113
World Accidental Deaths	20	26	26	112

a. Serious genetic and somatic health effects were calculated from radiation doses, assuming a linear dose-health effect relation. EPA dose-effect factors were used. Health effects from organ doses are not shown independently, but these organ health effects are included in these lines along with those caused by the whole body dose. (See Appendix B of this volume for more detail on methodology used in determining health effects.)

Total health effects (world population and work force) calculated from the radiation exposures range from 2 to 32 for Alternatives 1 and 2 as shown in Table I-4. Worldwide natural radiation dose during this same period will result in 120,000,000 health effects. As seen in Table I-4, total health effects are largest for Alternative 2B. Use of many ARB facilities, as assumed in this alternative, results in higher radiation exposure and larger total health effects. The health effects were calculated with EPA dose-effect factors, assuming no threshold dose. These dose-effect estimates are quite uncertain and may either underestimate or overestimate the actual effects.

Occupational radiation exposures are also summarized in Table I-4. Again, doses are large if the disposition facility is delayed and are largest for Alternative 2B.

The number of fatalities expected in the work force, including transportation and construction workers as well as those required to operate the ISFS or ARB facilities range from 11 to 42 for Alternatives 1 and 2. For perspective, the number of accidental deaths estimated over the entire period for these alternatives can be compared with 12,500 deaths in the year 1976 from occupational accidents in the U.S.

As indicated earlier, for Alternative 2B, transshipment of spent fuel between reactor discharge basins is minimized by use of the ARB facilities. The principal advantage of not allowing transshipment of spent fuel is to reduce transportation activities. This results in a decreased exposure of about four man-rem to the public and about 50 man-rem to transportation workers. The principal disadvantage is that additional storage basins are needed and this results in an expected increased exposure to the public of up to 5000 man-rem.

For alternatives which consider a year 2010 startup of disposition facilities (Alternatives 3 and 4), world population dose commitments range from 46,000 man-rem for Alternatives 3A, 3B, and 4A using ISFS facilities to 85,000 man-rem for Alternative 4B using ARB facilities. About half of these doses are received by the population within 80 km (50 mi) of facilities. To place these dose commitments in perspective, they are a very small fraction of the exposure from natural radiation sources in the same period [about 400,000,000,000 man-rem to the world population and 35,000,000 man-rem to the 80 km (50 mi) radius population]. These comparative values are different from those used in comparing the environmental effects of Alternatives 1 and 2 earlier due to different lengths of the studies between Alternatives 1 and 2, and Alternatives 3 and 4.

C Total health effects (world population and work force) calculated from radiation exposures range from 34 to 38 for Alternatives 3A, 3B, and 4A, to 113 for Alternative 4B as shown in Table I-5. Total health effects are highest for Alternative 4B because use of many ARB facilities to provide storage in that alternative results in higher radiation exposure and larger total health effects. The health effects were calculated with EPA dose-effect factors, assuming no threshold dose. These dose-effect estimates are quite uncertain and may either underestimate or overestimate the actual effects.

Occupational radiation exposures are also summarized in Table I-5. Again, doses are largest for Alternative 4B which uses many ARB facilities.

Risks from Accidents

The analysis concludes that the environmental risks from major abnormal events and accidents in Alternatives 1 and 2 are very small and essentially the same for these alternatives.
C The environmental risks were not determined for Alternaties 3 and 4, but the risks for these alternatives would be proportional to those of Alternatives 1 and 2, corrected for the changes in program size and duration. The maximum individual doses following abnormal natural events (e.g., tornadoes) and severe accidents (e.g., criticality) that might occur during operation of the facilities are all below one rem, and the probability of these events occurring is very low. Somewhat greater consequences are estimated for transportation activities in which the shipping cask is accidentally breached in an extreme accident. However, the risk is small because of the low probability of cask failure.
8-b No near-term biological effects of any significance are expected from the accidents analyzed.

Safeguards

Transportation and storage activities with spent fuel involve radioactive and fissionable material which can, under specific circumstances, be misused to create an unacceptable public consequence. The spent fuel will, therefore, be safeguarded; and the efficiency of the safeguards is considered in the environmental analysis. However, compared with other fissionable material in the LWR fuel cycle, spent fuel is relatively easy to safeguard
C because of its intense radiation. In addition, the radiological consequences that could occur from the most credible sabotage scenarios involving spent fuel are comparable to those consequences that could be encountered for comparable sabotage scenarios not involving nuclear material. Property damage resulting from

sabotage incidents would consist mostly of localized contamination, which would necessitate limiting access to the area until cleanup operations could be completed. It is concluded that the alternatives described in this volume do not impose an unacceptable safeguards risk or hazard to the public.

SUMMARY

The activities associated with implementing or not implementing
C the proposed policy are similar for a given disposition facility
startup date, and environmental impacts vary with the amount
of fuel received, the number of ISFS facilities required, the
storage time, and to a lesser degree to the amount of spent
fuel transported. One major difference between alternatives
is the extent of U.S. Government involvement in providing
facilities and management for the stored fuel. U.S. Government
involvement is assumed to be greatest in the centralized storage
option, less in the decentralized storage option, and none in
the "Policy Not Implemented" case.

The environmental impacts from all alternatives considered,
either from implementing or not implementing the spent fuel
storage policy, are small. The decreased resource consump-
tions and environmental impacts of alternatives that assume
reactor discharge basin operation at less than full-core
reserve must be balanced against the reduced flexibility in
reactor operation and the possibility of forced shutdowns
which could lead to the use of higher-cost substitute power
2-a or reduction of electrical power generation. Providing
2-d full-core reserve capacity is prudent and economical to avoid
4-a reactor outages due to inspections or emergency situations.
Full-core reserve capacity should be provided by either the
government or utilities. The impacts for decentralized ISFSs
providing full-core reserve are considered the same for either
government or private facilities. Nevertheless, utilities
have operated without full-core reserve rather than shut down.
Utilities may choose to operate without full-core reserve to
defer commitments to new storage facilities. Utilities may
also operate at less than full-core reserve if prevented from
providing the storage capacity due to institutional or regu-
latory constraints. At-reactor storage increases environmental
effects compared with ISFS basin storage because additional
storage basins are constructed and operated. However, the
impacts are relatively small compared with available resources
and risks from natural radiation sources.

1-a In view of the analysis contained in this volume, DOE prefers the following proposed action. The Spent Fuel Storage Policy should be implemented by the U.S. Government taking title to spent fuel which is offered by domestic utilities and storing it at ISFS facilities. The U.S. Government should provide sufficient storage capacity to allow U.S. utility reactors to maintain full-core reserve storage capacity. This storage capacity should be provided by either centralized ISFS facilities (Alternatives 1A and 3A) or smaller decentralized ISFS facilities (Alternatives 1B-1 and 3B).

REFERENCES FOR SECTION I

C 1. Draft Environmental Impact Statement — Storage of U.S. Spent Power Reactor Fuel. USDOE Report DOE/EIS-0015-D, U.S. Department of Energy, Washington, DC (August 1978).

6-b 2. Report to the President by the Interagency Review Group on Nuclear Waste Management. Report TID-28817, Interagency Review Group on Nuclear Waste Management established by President Carter in March 1978, Washington, DC (October 1978).

3. Report to the President by the Interagency Review Group on Nuclear Waste Management. Report TID-29442, Interagency Review Group on Nuclear Waste Management established by President Carter in March 1978, Washington, DC (March 1979).

II. BACKGROUND

A. Introduction

A national policy for interim storage of spent nuclear reactor fuels was announced by the United States Government on October 18, 1977.[1] This policy is reproduced as Appendix A of Volume 1 of this EIS. The policy covers domestic and some foreign fuels. Volume 2 of this environmental impact statement analyzes the environmental effect of storing domestic fuel under the new policy; the environmental effect of storing foreign fuel is analyzed in Volume 3. This volume (Volume 2) analyzes the environmental effects of interim storage and of transportation of the U.S. spent fuels that may be affected by the policy. It also evaluates the impacts of not implementing the policy. The details of the implementation of this policy have not been formulated; therefore, this statement is generic in nature, rather than site specific.

2-b Most nuclear power plants in operation today and most under construction were designed and licensed under the premise that their spent fuel would be reprocessed after a short period of cooling. The President's April 1977 announcement suspending reprocessing introduced uncertainty into utility planning. Since utilities had planned to have their fuel reprocessed, most had provided space in their reactor discharge basins for storage of about one and one-third reactor core discharges.

The U.S. Government proposed the Spent Fuel Policy to help alleviate utility uncertainty. Under this policy the government would supply limited interim storage space until a repository could be provided for nuclear wastes (either as wastes from reprocessing or in the form of unreprocessed spent fuel). Under this policy the government would encourage industry to provide as much of their own storage capacity as possible. Analyses on providing this additional storage capacity show that the most economical and environmentally beneficial means of providing such capacity is by better utilization of existing reactor discharge basins. The utilities have responded well as indicated by a recent NRC statement[2] that 65 of the 69 reactors operating on December 31, 1978, have plans to expand their reactor discharge basin storage capacity by increasing storage density. However, this increased storage capacity is inadequate; and some additional capacity will be needed. The amount of additional capacity required will depend upon the options selected and implemented by each utility.

2-b The cost of interim storage (which may be provided either by the U.S. Government or utilities) is a small fraction of the cost of providing electric power (see Volume 4). As long as this is true, the cost of interim storage should not influence any utility decisions for construction of future nuclear power plants.

The remainder of this section describes the policy and the types and quantities of domestic spent fuels that could be affected by the new policy. Interim storage options are included to give an overall perspective of types of facilities that could be used to implement the policy. This section concludes with a review of the environmental controls and safeguard considerations of this action.

C

B. U.S. Spent Fuel Storage Policy

The U.S. Government is proposing to accept and take title to spent nuclear fuel from utilities on payment of a storage fee to the government. The new policy is an extension of the President's decision to defer indefinitely all civilian reprocessing of spent fuel in the U.S. President Carter also asked other countries to join the U.S. in deferring use of reprocessing technology in order to evaluate alternative fuel cycles and processes which may reduce the risk of nuclear proliferation. Pending this evaluation, utilities are faced with the prospect of storing fuel discharged from reactors for an indefinite period with no approved plan for ultimately disposing of it. This produces an increasing uncertainty in economic calculations of the utilities, making advance planning difficult.

C In conjunction with the proposed implementation of the U.S. Spent Fuel Storage Policy, DOE proposes to encourage utilities to store their own fuel. DOE could encourage utilities to store their own fuel in a variety of ways, from making policy statements to providing direct financial incentives.

The major barrier to any new spent-fuel storage construction at existing reactor sites is the perception that such action would result in de facto permanent storage. State and local governments and interested citizens also perceive that increased onsite storage may serve to diminish the sense of urgency in dealing with waste disposal. Several states have already opposed reracking and new pool construction on this basis. Public policy statements by the U.S. Government should quell some of the state and local apprehension.

1-b
1-c

Public participation on issues related to this policy are essential. To stimulate this public participation, DOE prepared three draft environmental impact statements and a supplement: Storage of U.S. Spent Power Reactor Fuel (DOE/EIS-0015-D and DOE/EIS-0015-DS), Storage of Foreign Spent Power Reactor Fuel (DOE/EIS-0040-D), and Charge for Spent Fuel Storage (DOE/EIS-0041-D). These draft EISs have been incorporated into a five-volume set of the Final Environmental Impact Statement, U.S. Spent Fuel Policy (DOE/EIS-0015). As required by the National Environmental Policy Act (NEPA), public comments were solicited on the three draft EISs.

1-b
1-c

If the decision is made to implement the Spent Fuel Storage Policy, an away-from-reactor spent fuel storage facilities EIS (AFR EIS) will be prepared to provide the environmental input into the selection of facilities to meet the demand for spent fuel storage. The demand for spent fuel storage will be developed by using the latest available data as supplied by utilities concerning their plans for expansion, compaction, transshipments, and the expected quantities of spent fuel discharges. The environmental effects associated with the construction and/or operation of the facilities and the transportation effects associated with the available options will be evaluated.

C

As proposed in the Spent Nuclear Fuel Act of 1979 (see Appendix B of Volume 1), ISFS facilities for interim storage of spent fuel will be licensed by the Nuclear Regulatory Commission (NRC). The NRC licensing process will provide additional public input.

C. Characteristics of Spent Fuel

Although the policy does not exclude any type of nuclear fuel, the predominant power reactors in the U.S. are light water reactors (LWRs). This fuel is metal-clad uranium dioxide (UO_2) in which the readily fissionable uranium-235 has been enriched from 0.7% to 3 or 4%. The balance of the uranium consists primarily of relatively nonfissionable uranium-238.

Two types of LWR fuel are in use in the United States. Although similar, the fuel assemblies for pressurized water reactors (PWRs) and boiling water reactors (BWRs) differ somewhat in design as shown in Figure II-1. They also differ in size and in the quantity of fuel contained.

The LWR fuel is in the form of UO_2 pellets encased in either stainless steel or zirconium alloy (Zircaloy) tubes. The pellets are formed from UO_2 powder in a hydraulic press. They are heated in a sintering oven to achieve the required high density and then ground to close dimensional tolerances. The cladding materials used to encase the pellets (to form fuel rods) are normally Zircaloy alloys which have been welded and drawn or formed into seamless tubing.

The fuel rods are assembled into bundles (fuel assemblies) in a square array, each rod spaced and supported by grid structures and end pieces. The assembly is highly resistant to corrosion.

3-g The storage of other types of power reactor fuel should not result in environmental impacts that differ significantly from the impacts of storage of LWR and HWR fuel considered in the draft EISs. DOE has in its planning stages consideration of fuels other than standard LWR and HWR fuels.

When fuel can no longer sustain a nuclear chain reaction at economic power levels, it is considered to be spent and is removed from the reactor. About one-third to one-fourth of the LWR fuel is removed each year and replaced by fresh fuel. At discharge, each spent fuel assembly contains fissile isotopes (about 4 grams of fissile plutonium and about eight grams of uranium-235/kg of uranium) and about 98% of the uranium-238 originally charged. In addition to the plutonium, the spent fuel contains fission products and other waste radionuclides formed during irradiation. The waste nuclides occur both in the uranium oxide fuel matrix and in the hardware components of the fuel assembly. Radioactive decay of the unstable nuclides produces intense radioactivity and considerable heat. These radioactive materials in the spent fuel must be isolated from the environment.

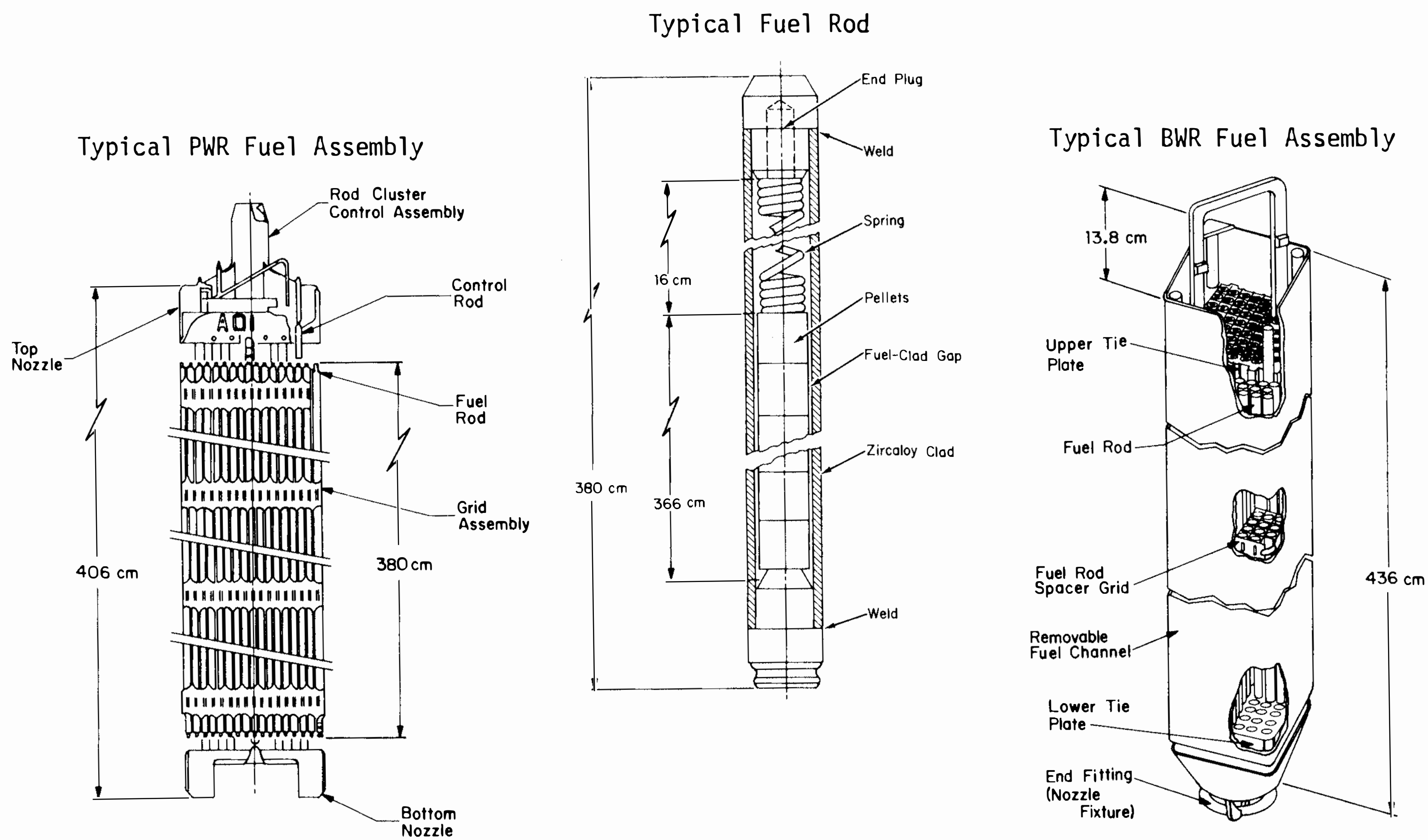


FIGURE II-1. Typical LWR Fuel Assemblies

The radionuclide concentrations and the heat generation from typical PWR fuel were calculated with the ORIGEN[3] computer code. They are shown in Table II-1 for fuel at discharge and at two and C five years following discharge. Only those radionuclides that contribute significantly to offsite dose are included in the table. Activities are shown for activation products (primarily in the hardware components), fission products (in the fuel matrix), and transuranics (also in the fuel matrix). Table II-1 shows that fission products and thermal power of spent fuel cooled for two years is less than 1% of that for fresh spent fuel. Cooling for an additional three years results in further reduction of less than a factor of three. Activation and transuranium products decrease more slowly. Additional information on the effects of cooling time on the radioactivity and heat generation in spent 1-d fuel is given in Section I of Reference 4. For the purpose of this generic EIS, a spent fuel cooling time of five years was used to establish spent fuel storage capacity requirements and four-year cooled fuel was used to allow calculation of environmental impact. DOE is currently performing studies on technical criteria for spent fuel acceptance. If the decision is made to implement the Spent Fuel Storage Policy, these technical criteria will be identified in the AFR EIS that DOE will prepare to provide the environmental input into the selection of facilities to meet the demand for spent fuel storage (see "Foreword").

On the average, the fission product radioactivity decays to about 0.1% of the original level in 300 years. In contrast, plutonium-239 in spent fuel requires about 250,000 years to decay to 0.1% of its original activity. Because of these differences in decay rates, the need for shielding and cooling decreases more rapidly than the need for isolation of the waste.

D. Projections of Quantity of Spent Fuel

The amount of irradiated nuclear fuel to be transferred to the U.S. Government for storage under the Spent Fuel Storage Policy will depend upon:

- The quantity of spent fuel discharged from the reactors

- The storage capacity available to the utilities in existing basins, expansions, or new basins

- The requirements for reserve capacity in reactor basins beyond the capacity to accommodate normal fuel discharges.

Each of these parameters is discussed below.

TABLE II-1

Radioactivity and Thermal Power in Spent LWR Fuel[a] per MT Uranium Charged to Reactor

		Years After Discharge		
		0	*2*	5
	Radionuclide Content, curies			
	Important Activation Products			
	^{14}C[b]	6.6×10^{-1}	6.6×10^{-1}	6.6×10^{-1}
	^{55}Fe	2.0×10^{3}	1.2×10^{3}	5.2×10^{2}
	^{60}Co	6.3×10^{3}	4.8×10^{3}	3.3×10^{3}
	^{63}Ni	5.5×10^{2}	5.5×10^{2}	5.3×10^{2}
	^{95}Zr	2.8×10^{4}	1.2×10^{1}	1.0×10^{-4}
	Total Activation Products	1.4×10^{5}	6.7×10^{3}	4.3×10^{3}
	Important Fission Products			
E	^{3}H	5.1×10^{2}	4.6×10^{2}	3.9×10^{2}
	^{85}Kr	1.1×10^{4}	1.0×10^{4}	8.3×10^{3}
	^{90}Sr	7.8×10^{4}	7.5×10^{4}	6.9×10^{4}
	^{106}Ru	5.3×10^{5}	1.3×10^{5}	1.7×10^{4}
	^{129}I	3.7×10^{-2}	3.7×10^{-2}	3.7×10^{-2}
	^{137}Cs	1.1×10^{5}	1.0×10^{5}	9.6×10^{4}
	Total Fission Products	1.4×10^{8}	1.2×10^{6}	4.8×10^{5}
	Important Transuranium Products			
	^{238}Pu	2.7×10^{3}	2.8×10^{3}	2.8×10^{3}
	^{239}Pu	3.2×10^{2}	3.2×10^{2}	3.2×10^{2}
	^{240}Pu	4.7×10^{2}	4.7×10^{2}	4.7×10^{2}
	^{241}Pu	1.0×10^{5}	9.4×10^{4}	8.1×10^{4}
	^{241}Am	8.4×10^{1}	4.0×10^{2}	8.0×10^{2}
	^{244}Cm	2.2×10^{3}	2.1×10^{3}	1.8×10^{3}
E	Total Transuranium Products	3.8×10^{7}	1.0×10^{5}	8.7×10^{4}
	Thermal Power, Watts	1.0×10^{6}	5.9×10^{3}	2.1×10^{3}

a. Calculated with the ORIGEN code for PWR fuel irradiated to 33,000 MWD/MTU at a specific power of 30 MW/MTU.

C| *b.* Based upon 2.5 ppm nitrogen (by weight) in UO_2.

Fuel Discharge Forecasts

The forecasts used in this report for the quantities of and schedule for nuclear fuel discharged from power reactors in the U.S. are based upon an assumed nuclear generating capacity of 380 GWe by the end of CY-2000. Besides the possible uncertainties in generating capacity, the actual amount of spent fuel discharged from each reactor also will vary, depending upon plant capacity factor, fuel burnup, etc. The nominal exposure for PWR fuel is 33,000 MWD/MT. For BWR fuel, it is 27,000 MWD/MT. Some fuel may be replaced at lower exposures, based upon utility plans which consider peak electrical demands and maintenance requirements. Several forecasts of fuel discharge are shown in Table II-2 and Figure II-2. As can be seen, these forecasts cover a range of about 25% with the exception of the more recent NRC forecasts[2] which are based on 230 GWe by the end of CY-2000.

In this volume, the Nuclear Assurance Corporation (NAC) forecast[5,6] was used as the basis for the spent fuel discharge schedules. This forecast was based upon a 1977 survey of utilities to determine their best estimate of near-term reactor discharge schedules and plant operating efficiencies. These near-term utility forecasts were then combined with the expected plant efficiency factors to estimate reactor capacities that are required to reach the 380 GWe generating capacity by CY-2000. These schedules of generating capacity were then used to estimate spent fuel discharges. This approach provides an upper limit forecast of spent fuel inventory which will maximize the environmental effects calculated for the Spent Fuel Storage Policy.

The next several paragraphs describe the relative benefits that can be achieved by more-efficient use of existing at-reactor basin space.

Storage Capacity

Most nuclear power plants were designed to accommodate the equivalent of one and one-third reactor loadings of irradiated fuel in their onsite storage pools in anticipation of prompt reprocessing. The storage racks originally supplied with the reactors differ from BWRs and PWRs.[2]

- The BWR has a rack design which is supplied by the reactor manufacturer. Individual rack positions have a 15-centimeter-square (6-inch-square) opening to receive the 14-centimeter-square (5.5-inch-square) fuel assembly. The two rows of fuel assemblies are separated by a distance of 14 centimeters (5.5 inches. This is the equivalent of 29 centimeter (7.5 inches) center-to-center separation . Racks are supported at the base and provided with cross-pool supports to provide seismic protection if required.

TABLE II-2

Forecasts of Domestic Fuel Discharged, MTU[a]

Year	*Source:*	*NRC*[2] *(1979)*	*DOE 1977 (NEP of NuFuel)*[7]	*Blomeke*[8]	*NAC April 1977*[5]
1976		-	2000	2200	1925
1977		-	1000	1113	1034
1978		-	1000	1225	1357
1979		1420	1300	1383	1525
1980		1520	1300	1511	1863
1981		1640	1400	1658	1896
1982		2100	1600	1786	2473
1983		2100	1900	1993	2876
1984		2300	2200	2279	3240
1985		2440	2700	2620	3981
1986		2650	2900	3043	4316
1987		2840	3400	3445	4731
1988		3050	3600	3791	5038
1989		3300	3900	4115	5229
1990		3600	4200	4444	5190
1991		3720	4600	4796	5251
1992		3950	4900	5171	5660
1993		4200	5200	5664	6115
1994		4380	5700	5965	6550
1995		4620	6000	6392	7007
1996		4840	6500	6852	7506
1997		5100	6900	7324	8009
1998		5460	7300	7787	8510
1999		5730	7800	8249	9010
2000		5800	8100	8699	9510
Total		81,700[b]	97,400	103,505	119,802

a. All forecasts are based upon an assumed nuclear generating capacity of 380 GWe by the end of CY-2000 with the exception of the 1979 NRC forecast which is based on 230 GWe.

b. Total includes about 4700 MTU discharged prior to 1979 and stored in reactor basins or AFR's at the end of 1978.

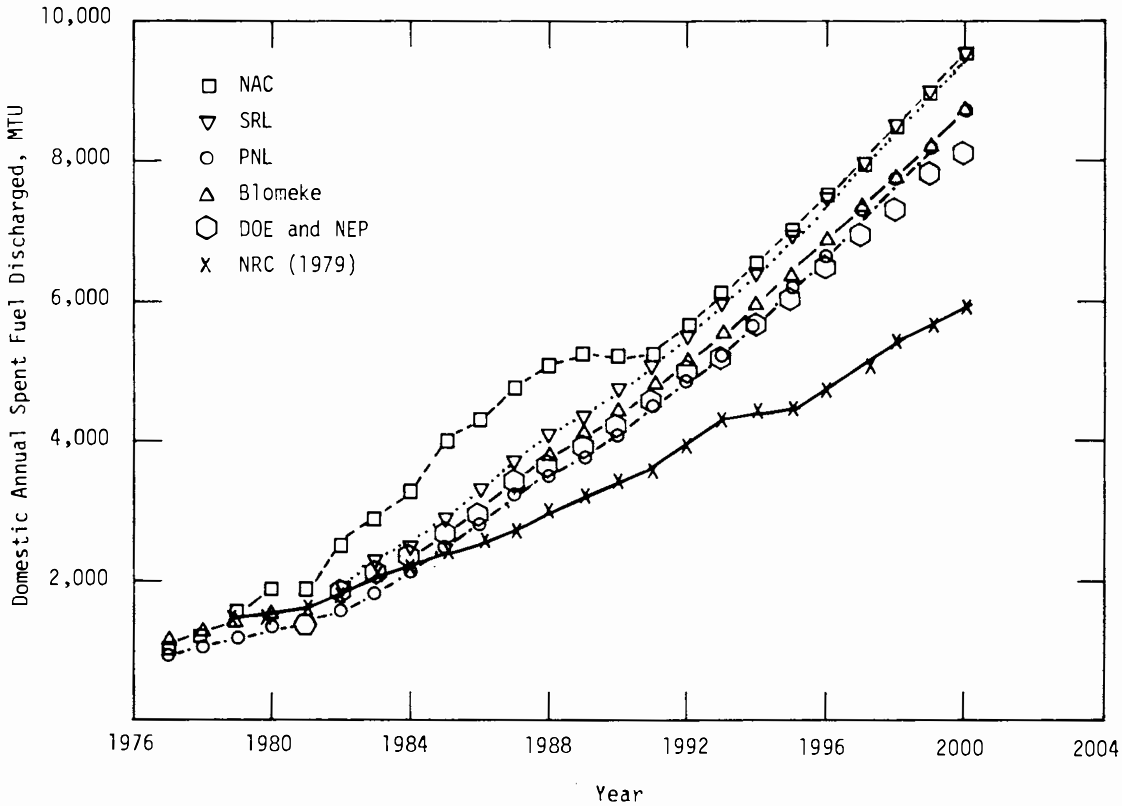
C 

FIGURE II-2. Forecasts of Fuel Discharged (Annual)

- The PWR racks may be provided by the architect-engineer (AE) or purchased by the utility to specifications of the reactor manufacturer. This arrangement results in a number of rack design variations. However, most racks are made of stainless steel with preformed angles to form corners for support of the fuel. Most of the racks have a 51- to 53-centimeter (20- to 21-inch) center-to-center spacing for the fuel assemblies in a square array. The individual spaces in each rack are 20 to 23 centimeters square (8 to 9 inches) to receive fuel assemblies 19 to 22 centimeters square (7.5 to 8.5 inches square).

4-a A fundamental assumption of the EIS is that, in the absence of implementation of the Spent Fuel Storage Policy, appropriate actions would be taken by the utilities to avoid forced shutdowns. This assumption is supported by the fact that, as of December 31, 1978, 65 of the 69 then-operating reactors had either been licensed to expand their capacity to store spent fuel in reactor discharge basins or were seeking such licensing. If utilities provide their own storage, options to them include a) reducing the space between stored assemblies with neutron absorbers in the storage

4-a array (compact storage), b) using stacked storage (i.e., double
tiering the storage racks), and c) disassembling the fuel bundle
and placing the individual fuel elements in a more-compact arrange-
ment (i.e. "pin storage"). Some utilities will not or cannot
3-b expand reactor discharge capacity; therefore, transportation of
spent fuel to other reactor discharge basins or to ISFS facilities
will be required to provide the needed storage capacity at the
affected reactor. Storage needs of utilities will be periodically
updated and will be used to revise the forecast of capacity of
ISFS facilities that the U.S. Government should provide under
this policy.

- Compact Storage. Storage capacity can be increased by more
than 200% over the initial capacity by closer spacing combined
with the use of neutron-absorbing materials in storage racks.
C A majority of utilities have either increased storage basin
density or have plans to increase storage density by this method.

- Materials which are available for use as neutron absorbers to
increase the storage capacity of existing reactor pools above
the initial design capacity are stainless steel, Boral (a mix-
ture of B_4C in aluminum, encased with aluminum), or stainless
E steel alloyed with boron or other neutron poisons (e.g. cadmium)
placed in the storage array.

3-d - Stacked Storage. Storage capacity in spent fuel pools can be
increased by stacking spent fuel storage racks on top of other
racks (i.e., stacked storage). This concept requires deep
pools to ensure that the water depth over the stacks is suffi-
cient to provide radiation shielding during both spent fuel
handling and storage. Two reactors have plans to increase
storage density by this method.

Storage capacity can almost be doubled over the initial capacity of the pool without the use of neutron-absorbing materials in the storage racks by utilizing stacked storage.

Stacked storage at more than a few facilities is a complicated engineering problem, and widespread use is not anticipated because pool depth is not sufficient to provide adequate shielding during handling operation. Most storage pools are about 12 meters (40 feet deep). Fuel assemblies are stored vertically in racks at the bottom of the pool. The fuel assemblies must remain submerged during removal and insertion into the racks to provide shielding; therefore, a deep pool is required. In those reactors where stacked storage is proposed, fuel is less than three meters (ten feet) in length, and stacked storage can be accommodated without pool modifications or special shielding.

C • "Pin Storage." Disassembly of the fuel bundle and placement of the individual fuel elements in a canister is a method with the potential to provide the largest gain in storage capacity of existing reactor storage pools. This concept is called "pin
3-c storage." Although not presently approved, this method can increase the storage density by at least a factor of two over compact storage methods in which the assembly is left intact.[2]

NAC has performed an assessment[9] of several alternatives for increasing storage capacity at existing reactor pools. That assessment has identified no safety or environmental issues that would preclude licensing of the "pin storage" concept. Special administrative and operating controls may be required to meet increased safeguards concerns if this method were selected.

Fuel assemblies were designed for diassembly and have been
3-g disassembled. At this time, one utility has plans to increase storage density of its spent fuel pool by the "pin storage" concept.

NAC[5,6] storage basin capacities are used in this Environmental Impact Statement. These are based upon current reactor basin storage capacities and 1977 plans by utilities to increase capacity by storage compaction or basin expansion. This forecast is judged to be a conservative indication of the actual basin capacity for at least the first ten years of the forecast.

Reserve Capacity

2-a Providing full-core reserve capacity is prudent and
2-c economical to avoid reactor outages due to inspections or
2-d emergency situations. Capability for achieving full-core reserve
4-a should be provided by either the government or utilities and the impacts for decentralized ISFSs providing full-core reserve are considered the same for either government or private facilities. Nevertheless, utilities have operated without full-core reserve rather than shut down. Utilities may choose to operate without full-core reserve to defer commitments to new storage facilities. Utilities may also operate at less than full-core reserve if prevented from providing the storage capacity due to institutional or regulatory constraints.

The amount of reserve space that should be maintained in a reactor basin is a matter of judgment for each utility. DOE does not consider it to be a safety consideration, but it is an economic consideration. Full-core reserve is not required by the NRC. The effects of a likely range of options open to the utilities are analyzed in this EIS. A fundamental premise has been that appropriate actions will be taken to avoid forced shutdowns (see discussion in C.2.1). Full-core reserve capacity is one such measure.

C Figure II-3 provides several scenarios or the total amount of domestic fuel that could be delivered to the U.S. Government under this policy either to interim storage basins or to a disposition facility. In these scenarios the NAC[5,6] forecast of fuel discharged and basin capacity forecasts are assumed. It is also assumed that the utilities either 1) maintain discharge capability,* 2) maintain a full-core reserve** or 3) transfer to the government all spent fuel when it has cooled five years. Lower estimates, (not shown in Figure II-3) based upon a lower fuel charge schedule (given on Table II-2) would result if a utility elects to maintain minimum free space in the reactor discharge basin. Lower estimates would also result if a utility increases storage capacity significantly above that considered in the NAC forecast or if the U.S. requires less electrical power generation from nuclear reactors. If a lower discharge schedule is assumed, less spent fuel would be transferred to the United Stated Government under the policy.

C The timing of the disposition action for spent fuel is important in determining the amount of interim storage that must be provided. The disposition mode may be disposal in a U.S. repository or reprocessing of spent fuel. In an effort to determine the effects of the disposition timing on storage requirements, a disposition facility is assumed to be available no earlier than the year 1985. It is assumed that the first four years of operation of the disposition facility would be at a reduced rate[11] to provide for startup uncertainties. After that period, the capacity of the disposition facility would be adequate to receive the forecast discharge of the spent fuel from power reactors, and no additional interim storage capacity would be required.

C Figure II-4 shows the interim storage requirements if the interim storage facility is available in the year 1983, and the disposition facility starts up in the year 1985. These requirements are estimated on the same three bases used in Figure II-3, that utilities desire to 1) maintain only discharge capability, 2) maintain full-core reserve, or 3) transfer to the government all spent fuel when it has cooled five years. The results given in Figure II-4 assume that a certain amount of spent fuel is transshipped between reactor basins at the planned rate shown in Table III-2 to lessen the need to ship spent fuel to centralized facilities.

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*Discharge capability requires capacity for normal discharge (about 1/3 of the reactor core) at its scheduled discharge time.

**Full core reserve assumes required capability to discharge all of the fuel contained in the reactor (equivalent to the normal discharge of about three years) at any time.

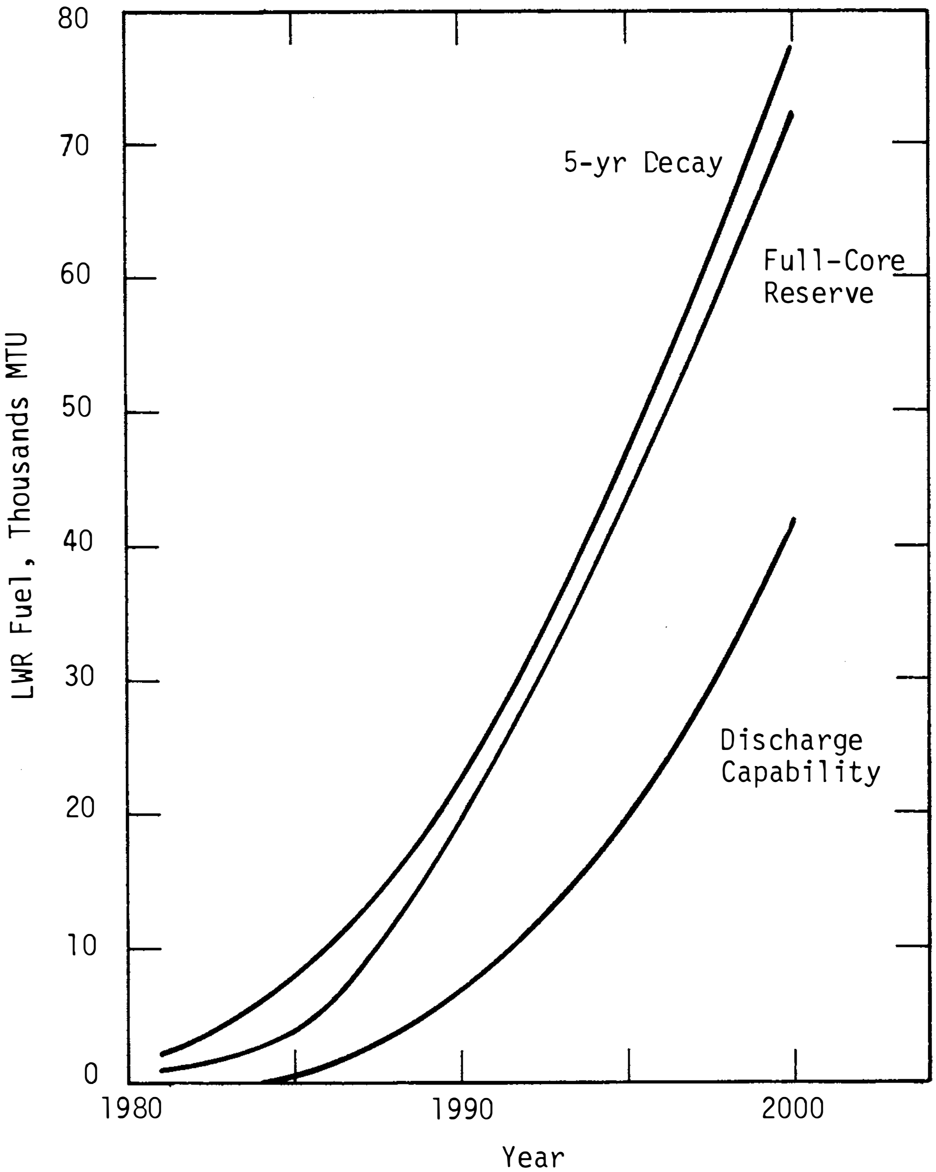


FIGURE II-3. Forecasts of Interim Storage Requirements in Addition to Reactor Discharge Basins

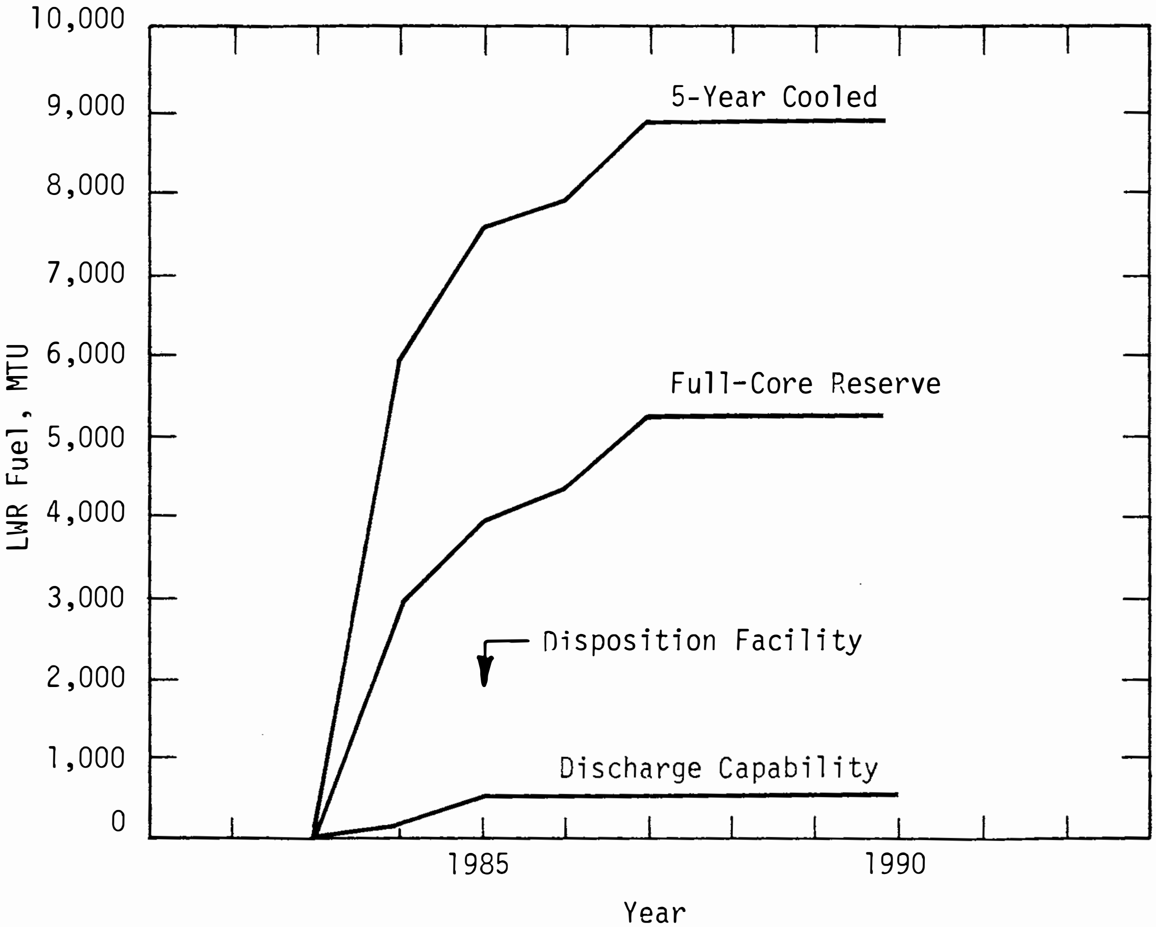


FIGURE II-4. Interim Spent Fuel Storage Requirements in Addition to Reactor Discharge Basins

Figure II-5 shows the influence of disposition facility startup date on interim storage capacity. The increasing slope of the fuel inventory results from the increasing rate of spent fuel discharges.

3-a A recent DOE report[10] analyzes the sensitivity of many variations that the utilities control in ISFS storage capacity. The information developed in this analysis is summarized in Figure II-5. This analysis identifies a planning case for DOE evaluations for needed storage capacity that has lower storage requirements for domestic fuel than those used for environmental evaluation in this EIS. This case is denoted as "Base Planning Case" and is shown in Figures II-5 and II-6. In DOE's judgment, this Base Planning Case represents the probable action of the utilities and, thus, best reflects the storage capacity that needs to be provided. DOE intends to update these surveys of capacity needed from time to time as new information becomes available.

The "Base Planning Case" represents an updating of earlier DOE estimates of required interim storage capacity, a revision of the type that will be made periodically throughout the program. It is not intended to represent the most likely case but rather a "best estimate for purposes of planning." As has been discussed previously in this section, many factors could affect the amount of fuel transferred to the government under the proposed Spent Fuel Policy including:

1) Amount of spent fuel pool expansion actually accomplished

2) Amount of transshipment allowed

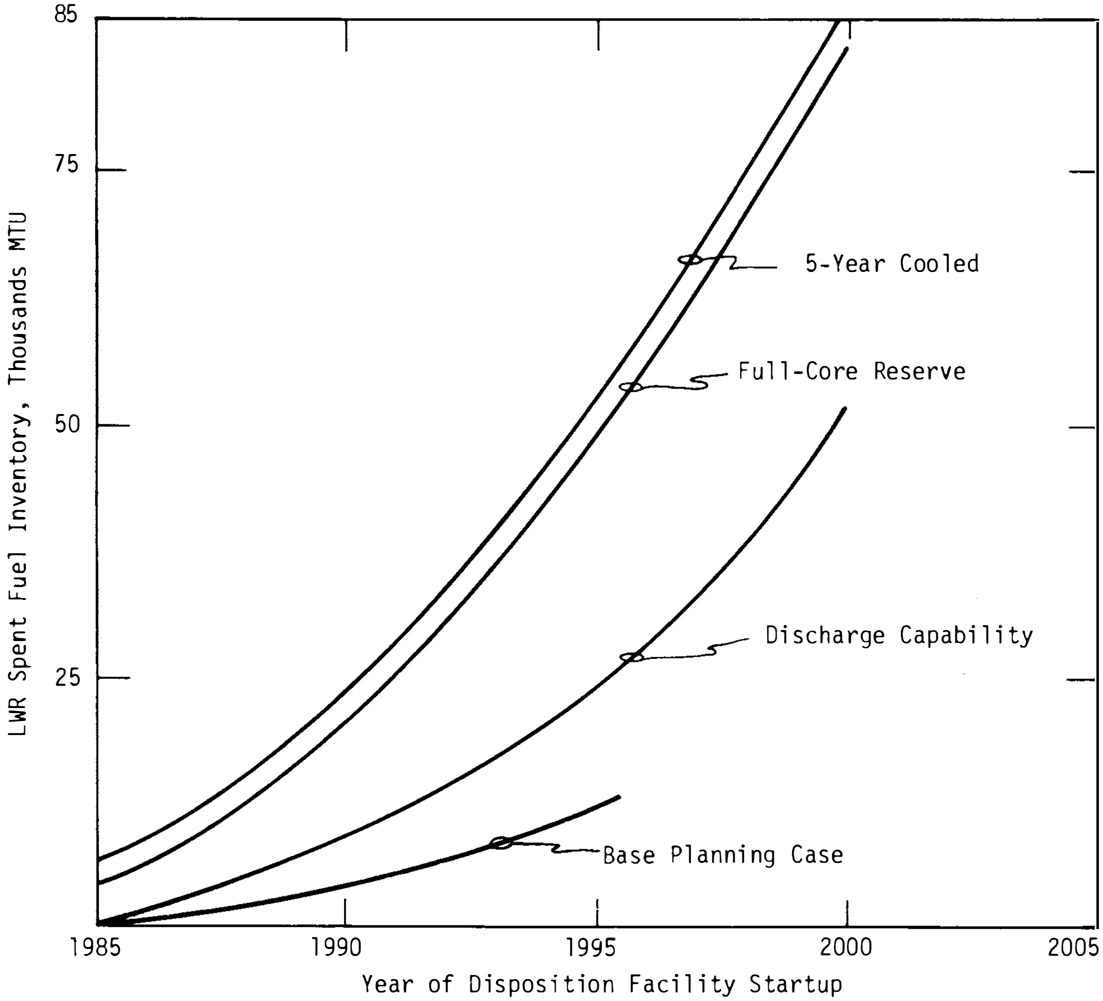
3) Reactor capacity factors achieved

4) Amount of discharge capability maintained, e.g., full-core reserve or discharge capability

5) Fuel changes to achieve higher burnups (thus less fuel discharged)

6) Time at which a disposition facility becomes operable

7) Total nuclear generating capacity between now and the year 2000).



3-a

FIGURE II-5. Interim Storage Capacity Dependence on Disposal Facility Startup *

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* Delay of disposition facility startup beyond the year 2000 is possible. See Section C.1.1.1 and Appendix E.

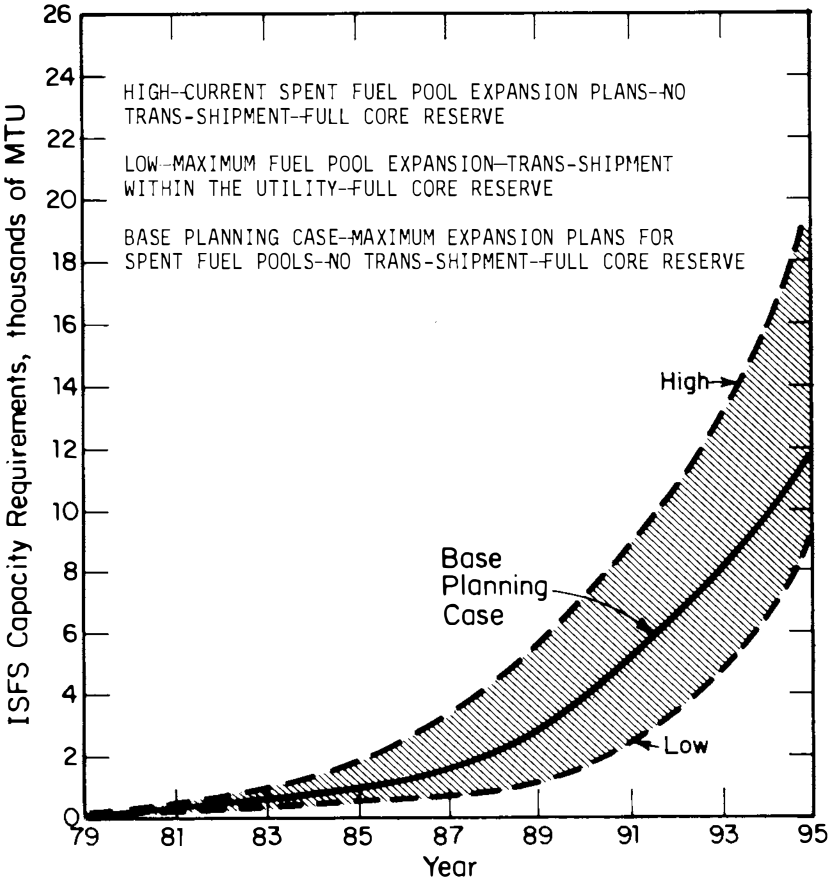

FIGURE II-6. Range of ISFS Capacity Requirements

3-a The environmental effects of this "Base Planning Case" were determined for a delayed startup of the disposition facility until the year 2010 and are given in Appendix E of this volume. The analyses in other sections of this volume do not use this "Base Planning Case." However, if the "Base Planning Case" had been selected the environmental effects would be less than those identified in the draft EIS because the interim storage requirements would have been less. If the policy is implemented, additional environmental impact statements prepared for specific ISFS site or facilities will use up-to-date surveys of utility plans for utilization of ISFS facilities.

E. Description of Interim Storage Facilities

E.1 Existing ISFS Facilities

Spent fuel is now stored primarily in reactor discharge basins. In some cases the limited storage capacity initially provided at the LWR sites is being increased by densification of storage.[2] A limited amount of fuel has been shipped to privately owned independent spent fuel storage (ISFS) facilities. Private ISFS facilities with some remaining storage capacity include those at the General Electric (GE) Morris Plant and the Nuclear Fuel Service (NFS) West Valley Plant. A third site, the Allied General Barnwell Plant, is completed but not licensed to receive and store spent fuel.

- GE Morris Plant. The storage basin at the General Electric reprocessing plant at Morris, Illinois, has been licensed as an ISFS facility. The initial storage capacity of about 90 MTU has been increased to about 750 MTU. Presently, this facility contains about 300 MTU of spent fuel and has contracts for additional fuel.

- NFS West Valley Plant. The storage basins at the Nuclear Fuel Service plant have a capacity for storing 260 MTU spent fuel.[2] This former reprocessing plant is now licensed and operating as an ISFS facility for spent fuel storage. The facility is currently storing 170 MTU spent fuel. NFS announced that it was withdrawing from the reprocessing business, and this plant is no longer receiving spent fuel from utilities for storage.[2]

- Allied General Barnwell Plant. A storage basin, similar to those at the GE and NFS plants, exists at the Allied General Barnwell Plant. The basin has approximately 400 MTU capacity.[2] Allied General has applied for a license to operate its basin for interim storage prior to startup of the reprocessing facility. The licensing effort proceeded to the hearing stage and was then suspended.

The 500-1000 MTU of unfilled ISFS facility space will become inadequate within a few years. As discussed in this report, a capacity of several thousand MTUs will be needed by the year 1985. The rest of this section describes options that could be developed to meet the needs.

E.2 Interim Storage Facility Alternatives

The need for additional interim storage space has prompted several investigations of fuel storage technologies.[2,12,13] The alternatives that have been considered include storage of unpackaged fuel in water-cooled basins or air-cooled vaults and storage of packaged fuel in water-cooled basins, air-cooled vaults, concrete surface silos (surface storage cask), geologic formations, or near-surface caissons. In Table II-3, these storage alternatives are compared.

One alternative for interim storage would be to use water-filled modular basins. Each of the basins would be a stainless-steel-lined concrete structure. The overall facility would be designed to 1) receive, handle, decontaminate, and reship spent fuel casks; 2) remove irradiated fuel from casks; 3) place the fuel in a storage basin; and 4) cool and control the quality of the water. The facility would also be designed for removing the spent fuel from the storage basins, loading it into shipping casks, decontaminating the loaded casks, and shipping the casks. The modular construction allows facility expansion with a minimum of additional support facilities and services.

All the storage facilities must be designed to protect the fuel cladding against mechanical, chemical, or thermal damage. The fuel cladding is the primary barrier for confining fuel-core material for all modes of spent fuel storage. The storage facilities must also provide a safe, subcritical arrangement of fuel assemblies and adequate shielding under normal operating conditions or during extreme natural phenomena.[14] Additional details are presented in References 2, 13, and 15.

Near-surface storage with forced-draft air cooling is feasible for unpackaged LWR fuel that has been out of the reactor for at least three to four years. This type facility would consist of reinforced concrete storage vaults with auxiliary equipment to circulate and filter the cooling air. The fuel would probably be stored vertically in sleeves supported by top and bottom tube sheets. The sleeves would form inlet and discharge plenums to divert cooling air to the fuel. Cooling air would normally enter the bottom plenum of the vault, and heated air would exit the top plenum.

Facilities which have natural draft cooling of spent fuel have also been proposed. These facilities are designed to use the decay heat from the residual fission products in the fuel to create a natural draft sufficient to cool the fuel. However, the pressure differential obtained in a natural draft system is inadequate to force the ventilating air through a filtration system.

TABLE II-3

Summary Comparison of Spent Fuel Interim Storage Alternatives

Storage Alternative	*Confinement Barriers in Addition to Cladding*	*Means of Heat Removal*	*Method of Controlling Fuel Cladding Corrosion*	*Maintenance Requirements*	*Surface Land Use*
Unpackaged Storage					
Water-cooled basin	Water[a]	Forced circulation of basin water	Low-temperature and water quality control	High	Low
Air-cooled vault	Filters	Forced circulation of air	Low temperature	Moderate	Moderate
Packaged Storage					
Water basin	Water and package[a]	Forced circulation of basin water	Packaged in inert or noncorrosive medium	High	Low
Air-cooled vault	Package	Natural circulation of air	Packaged in inert or noncorrosive medium	Low	Moderate
Concrete surface silo (surface storage cask)	Package	Natural circulation of or conduction to air	Packaged in inert of noncorrosive medium	Low	High
Geologic formations	Package hole liner[a]	Conduction to earth	Packaged in inert of noncorrosive medium	Moderate	Low
Near-surface caisson	Package, hole liner	Conduction to earth	Packaged in inert or noncorrosive medium	Low	High

a. Filtration of effluent ventilating air may be used to provide an additional confinement barrier.

To reduce the probability of radionuclide release, packaging of the fuel would probably be required. Such packaging may in fact be desirable in any of the systems in which fuel disposition is delayed for a long time, since it would reinforce cladding integrity during the long-term storage.

One natural-draft cooling alternative calls for a large concrete structure similar to the storage vault for forced-draft air cooling. Packaged fuel is suspended in metal sleeves. Cooling air enters the sides of the vault and passes up through and out the top of the sleeves to the exhaust stack. A second natural-draft cooling alternative consists of large cylindrical concrete housing (silos). The packaged fuel is cooled either by convection of air between the steel container and the concrete silo or by conduction through the concrete to the atmosphere. The cooling is completely passive in both of these alternatives; it requires little maintenance and only minimal surveillance. Container failure is detected by an area monitoring system, and the failed containers are removed from storage for repair and are returned to storage.

Two passive cooling alternatives in which the earth is used as a heat sink have also been tested. In one alternative, fuel packages are stored in holes near the earth's surface. In the other, encapsulated fuel is stored in holes in a mined geologic deposit (such as a bedded salt formation). In both of these alternatives, hole liners are used to protect the spent fuel packages against corrosion.

Beyond the limited ISFS facility capacity described in Section E.1 none of the options described above exist today as available options for this interim spent fuel storage. The interim storage in geologic deposits, as described in the previous paragraph, may become a viable option if a geologic repository for nuclear waste disposal becomes available, but will not affect the near-term need for additional interim storage capacity. Use of this same facility for interim storage and later for terminal storage would reduce the number of future interim storage facilities.

F. Benefits of Implementation

C The Spent Fuel Storage Policy was developed by the U.S. Government to help reduce some of the uncertainties created when spent fuel reprocessing was indefinitely deferred by Presidential Policy in April 1977. As concluded in a Senate Committee on Energy and Natural Resources report,[16] utility expansion of their own storage capacities have been hampered by changing regulations and intervenor actions. This Senate report points out the benefits the Spent Fuel Storage Policy will have in resolving these insti-

C tutional and regulatory considerations. The report also points out that implementation of the policy will allow the U.S. Government to provide the necessary storage capacity to ensure that no reactors are forced to shut down or curtail their delivery of power for reasons of inadequate spent fuel storage.

G. Relationship to Other Federal Programs

A number of other Federal programs may modify the implementation of the policy on spent fuel storage. The programs include:

Nonproliferation Alternative Systems Assessment Program (NASAP) - This program is being developed by DOE to implement the President's Nuclear Policy Statement of April 7, 1977. NASAP will identify and evaluate alternative nuclear fuel cycles. The objective of the program is to define fuel cycles that have potential for reducing the risks of nuclear weapon proliferation while still providing for the continued worldwide use of nuclear power. The spent fuel storage being evaluated in this volume is a key step toward alleviating uncertainties linked to the near-term disposition of spent fuel here and abroad.

International Nuclear Fuel Cycle Evaluation (INFCE) - This program is also an implementation of the President's Nuclear Policy Statement of April 7, 1977, and is similar to NASAP but with international participation. U.S. participation in the program is coordinated by the State Department. The spent fuel policy may provide spent fuel storage capacity and, thus, increase the time available for development of fuel cycles that reduce the risks of nuclear weapon proliferation under the INFCE and NASAP programs. Conversely the spent fuel policy may be influenced by the INFCE program because it may influence the method of disposition in the spent fuel policy.

Department of Energy Alternate Fuel Cycle Technology Programs - These ongoing programs will provide technical information to NASAP and INFCE on advanced fuel cycles with proliferation-resistant and safeguards features. Development of systems is included in these programs.

National Waste Terminal Storage (NWTS) - This program was established in February 1976, and represents the principal programmatic effort of DOE for disposal of commercial nuclear waste or spent fuel in a geologic formation(s). It interfaces with the disposition of spent fuel in this spent fuel policy. The original emphasis of the NWTS program was disposal of wastes from commercial reprocessing facilities. After the President's announcement of a plan to defer commercial reprocessing, the emphasis was shifted to disposal of spent fuel that might be classified as waste and to retrievable storage of spent fuel that might later be reprocessed.

C Waste Isolation Pilot Plant (WIPP) — The principal mission of WIPP was ultimate disposal of transuranic (TRU) waste from the national defense program.[17] The President recently stated[18] that "the Waste Isolation Pilot Plant (WIPP) Project should be canceled, since it is unlicensed and cannot accept commercial waste. The site of the proposed project in Carlsbad, NM, will be investigated further and if found qualified will be reserved for consideration along with other candidate sites in different geologic environments as a licensed repository for high level waste."

E EPA and NRC Programs — The EPA is developing criteria for disposal of all forms of radioactive waste. NRC is licensing expansions of spent fuel basins at reactors. NRC has prepared a generic environmental statement that evaluates "at-reactor" and "independent spent fuel" storage and supporting operations. A finding of the NRC environmental statement[2] is that storage of LWR fuels in water pools has an insignificant impact on the environment, whether at reactor sites or at independent spent fuel storage sites. The NRC GEIS indicates that, technically,
C reactor discharge basin storage capacity can be greatly expanded. With the assumed substantial expansion of reactor discharge basin storage capability, AFR storage requirement would not be eliminated.

H. Environmental Controls and Monitoring

C Environmental controls provided in the generic facilities considered in this EIS consist of the design features to reduce releases of radioactive and noxious materials to the environment. These controls are described in various sections of this volume. This section discusses the effluent and environmental monitoring programs associated with implementation of the policy.

The purpose of the effluent and environmental monitoring program for the spent fuel storage facilities is to:

- Determine if concentrations of radioactive materials in liquid and gaseous effluents are as low as practicable and meet all applicable regulations
- Evaluate adequacy of performance of the containment, the waste treatment methods, and the effluent controls
- Assess radiation dose to the public and public exposure to non-radioactive pollutants resulting from operation of the facilities
- Maintain surveillance for long-term buildup of radioactivity in the environment.

Because the radioactivity releases are predicted to be very low (see Section III), the limits of detection may preclude direct observation of these released radionuclides in the environment. Estimates of human exposure may, therefore, depend primarily upon detailed analysis of radionuclides at the points of release and suitable models for dispersion and movement of radionuclides through the environment. Parameters in the models will be determined from site-specific data with regard to meteorology, hydrology, demography, land and water use, water chemistry, and local food chains. Environmental monitoring will also serve to check on accumulation of radionuclides in the environment.

The monitoring program is conducted in two phases: 1) a preoperational phase before facility startup and 2) an operational phase beginning with facility startup and continuing throughout the life of the facility. The objectives of the preoperational phase are

- Evaluating environmental radiation levels and fluctuations attributable to natural background, fallout, and other sources. Media to be analyzed include air, water, soil, milk, other foodstuffs, sediment, and aquatic biota. Measurements emphasize analyses of specific radionuclides, whose origins may later be subject to doubt. Statistical evaluations of sources of measurement variability are also required.

- Identifying significant population groups, pathways, and radionuclides. This effort depends greatly upon parallel programs for the accumulation of meteorological, hydrological, and demographic data for the site, together with information on local food sources, land use, and trace element analysis of potential receiving waters.

- Developing and evaluating sampling and analysis techniques and procedures.

- Training appropriate personnel in the use of these techniques and procedures.

The early stage of the operational monitoring phase is a continuation of the preoperational phase. This operational monitoring phase will be particularly intensive during the first two or three years of facility operation with special programs and with frequent evaluation of data to develop better understanding of important pathways and behavior of radionuclides in the local environment.

Sampling focuses chiefly upon media impinging directly on man, such as air and water; upon foods consumed directly by man, such as milk, fish, and leafy vegetables; and upon media such as aquatic plants and sediments that may be sensitive indicators of the presence of radioactivity in the environment. Whenever practicable, samples are analyzed for specific radionuclides to permit dose estimates to be made for man and important biota. In addition, all potentially radioactive effluents are monitored at their point of release and analyzed in accordance with Nuclear Regulatory Commission guides. Provision is made for monitoring effluent discharge paths for radioactivity from normal operation, from operational incidents, and from accidents.

The radiological environmental monitoring program is supplemented, when warranted, by programs designed to assess the impact of nonradiological pollutants (including effects of plume drift from cooling towers) on the nearby environs. Although details cannot be specified for the generic facilities described in this environmental statement, the facilities would be designed and operated in compliance with the Federal Water Pollution Control Act of 1972 (PL 92-500) and Amendments for control of water pollution, the Federal Resource Conservation and Recovery Act of 1976 (PL 94-580) for solid waste disposal, and the Federal Clean Air Act and Amendments (PL 93-319) for control of air pollution. Appropriate monitoring of nonradioactive effluents will be provided to ensure compliance with these Federal laws and any other applicable Federal, state, and local laws.

I. Safeguards

C All facilities discussed in this volume are assumed to meet licensing requirements. Among other things, these requirements include 1) meeting general and specific safeguards criteria for facility protection, materials control, and personnel training; 2) developing approved procedures for facility operation that include safeguards requirements; and 3) monitoring these activities periodically to ensure the continuance and adequacy of safeguards protection.

Current requirements for safeguards protection of fixed site facilities and transportation of spent fuel and materials are listed, primarily, in applicable portions of 10 CFR 73.[14] Part 73 was added to the Federal Regulations in the year 1969 and has been modified several times. The most recent revision (July 30, 1979) adds to or revises 10 CFR 73[14] rather than replacing it. The requirements specify that vital equipment or special nuclear materials be located within areas protected by barriers, which, in turn, are within a fenced or walled protection area. The space between the protected area fence and the inner barrier must be

illuminated and monitored to detect abnormal presence or activities. Guards and watchmen must be suitably trained and equipped and must have communications with law enforcement authorities; access to protected and vital areas must be restricted; individuals authorized to enter such area without escort must wear coded picture badges; and vehicles inside the protected area must be escorted. All persons and packages entering protected areas are searched (employees who have specified security clearance and packages other than hand-carried ones may be searched at random). All packages that enter a material access area are searched, and all persons, packages, and vehicles researched upon leaving. Regulatory guides identifying methods of fulfilling these require-
C ments that are acceptable to NRC have been issued.[19]

Controls have also been designed to provide assurance that the nuclear materials are always present at their designated locations
C as required in 10 CFR 70.[20] These controls include preparation of detailed and current records on the form, quantity, and location of special nuclear materials (SNM) and the completion of material balances based upon physical inventories. The controls also include different administrative and operational procedures directed at maintaining current knowledge of nuclear material quantity and location and detecting any removal of such material from authorized locations. Methods include documented transfer of custodial responsibility and, at some facilities, regular and frequent piece count by operating personnel.

10-a Parts of 10 CFR 73 provide controls to ensure that spent reactor fuel in transport is also safeguarded.[21] 10 CFR 73 specifies that the licensee must make arrangements to ensure that 1) NRC has approved the transport route, 2) all vehicles are under constant surveillance during all stops, 3) transportation personnel have successfully completed the NRC training program, 4) emergency procedures have been developed, and 5) vehicles have been equipped with communication equipment and features to immobilize the shipment if stopped by a threatening group.

In addition to incorporating these requirements and controls, procedures will be instituted for response to threats of theft or sabotage. These procedures will provide for response to:

- Suspected or actual theft of SNM or other material which could present a radiological hazard
- Threat of sabotage to a facility containing such materials
- Threat involving the destructive use of such materials.

The primary response to any actual incident at an ISFS or ARB would be made by onsite guard forces. The primary response for incidents during transport would be to disable the vehicle or cask and then to notify nearby police. After the primary response, the Federal Bureau of Investigation, which has statutory responsibility for investigating such incidents, is notified. DOE and NRC would support the FBI with specialized technical assistance, especially in connection with the recovery of stolen material, and would undertake to determine if a potential hazard of dispersal by explosives or other illicit uses of the material existed. If a hazard were determined to exist, the different DOE offices responsible for implementing the established Radiological Assistance Plan[22] would be alerted or activated. This plan provides for advice and assistance in the areas of emergency evacuation and rescue, radiation monitoring, decontamination, and specialized emergency medical services where personnel are exposed to radiation.

This system of safeguards requirements, controls, procedures, and planned responses form a hierarchy that has been tested both in operation and in licensing procedures and found to be demonstrably adequate. No known incidents involving the theft or misuse of spent fuel have occurred to date.

The reduced safeguard risks from reduced transportation of spent fuel when using ARBs for storage are offset by the increased risks associated with the accumulation of larger quantities of spent fuel in a large number of new, ARB facilities.

Section IV of this volume includes a further discussion of safeguards considerations in the context of risk to the public during transportation and storage of spent fuel.

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III. ALTERNATIVES AND THEIR ENVIRONMENTAL EFFECTS

A. Introduction

This section describes the alternatives for providing interim storage for spent nuclear fuel before final disposition and the environmental effects of each alternative. Generic facilities and the environmental effects associated with each alternative are described briefly in this section and more fully in Appendices B, C, and D.

One alternative is to implement the Spent Fuel Policy announced by the U.S. Government in October 1977. In this alternative (Alternative 1), the U.S. Government would accept title to and provide management of spent nuclear fuel. Interim storage would be provided in either government-owned or private facilities. In Option A of this alternative (Alternative 1A), centralized storage is provided in a few large government-owned independent spent fuel storage (ISFS) facilities. In Option B of this alternative (Alternative 1B), decentralized storage is provided by retaining the spent fuel in reactor discharge basins to the extent consistent with continued reactor operation and by providing additional dispersed storage basins (under private or government ownership) as required. In Option B, two modes of operation are considered: in Alternative 1B-1, full-core reserve is assumed to be maintained in reactor discharge basins; and in Alternative 1B-2, annual discharge capability is assumed to be maintained. In Alternatives 1A and 1B, the U.S. Government will transfer the fuel to a disposition facility (either fuel reprocessing or a repository) when that facility becomes available.

The second alternative is the "Policy Not Implemented" case; that is, interim storage of spent nuclear fuel continues to be provided by private industry rather than the U.S. Government. In this alternative, the government has no responsibility over the spent fuel until it is delivered to the disposition facility. In Option A of this alternative (Alternative 2A), decentralized storage is provided by retaining the spent fuel in reactor discharge basins to the extent consistent with continued reactor operation and by providing additional dispersed storage basins (privately owned and away from reactors) as required. In Option B of this alternative (Alternative 2B), new privately owned storage basins (stand-alone facilities) are built on existing reactor sites for storage of spent fuel from the discharge basins of adjoining reactors until final disposition. Environmental effects of Alternative 2A and Alternative 1B-2 are essentially the same, since it is assumed that private industry would provide sufficient storage capability to prevent shutdown of existing nuclear plants. The difference in the two cases is that in Alternative 2A the utilities retain title to the spent fuel.

The options of not building future nuclear plants or shutting down existing plants to prevent generation of additional spent fuel are not examined in this volume since issues associated with these options are examined in impact statements for the construction of individual nuclear power plants. This issue is examined in the NRC GEIS on storage of spent fuel (NUREG-0575).[1]

In this section, only the potential environmental effects judged to be most significant are discussed. These include the use of natural resources and the radiological exposure from normal operations and accidents. Other effects (e.g., construction effects, thermal and nonradiological releases, effects on biota
C and secondary effects) are of lesser impact and are about equivalent in magnitude for the alternatives. These other
C effects are analyzed in later sections and in the appendices. Almost all effects are expected to be eliminated after the sites are restored following decommissioning (e.g., land commitments are expected to be small and temporary for the actions covered in this volume).

In each of the alternatives, the impacts of transporting about 72,200 MTU spent fuel and storing the amount of spent fuel specified is assessed. Potential impacts expected for 1985 startup of a disposition facility are compared with impacts expected if availability of the disposition facility is delayed beyond 1985.

C The alternatives analyzed in this section are those which appeared in the draft version of this EIS and are based on spent fuel flows forecasted in the latter part of 1977 and early 1978. Environmental analyses of alternatives based on a more recent forecast of fuel flows and also based on a delayed startup of the first disposition facility to the year 2010 are presented in Appendix E. The most recent DOE estimate of storage requirements was used for the analyses in Appendix E. Since the analyses for these newer alternatives are based on different fuel schedules, environmental effects are not directly comparable with the alternatives in this section. The new analysis from Appendix E was included to show the comparison of effects of implementing the U.S. Spent Fuel Storage Policy with not implementing the policy if the disposition facility is delayed beyond the year 2000.

B. Description of Generic Facilities

B.1 Water Basin

Modular water-cooled basin storage of unpackaged spent fuel is selected as the generic method for interim storage in this volume because it is a proven concept that is acceptable to the NRC. The technology of water-cooled basin storage is well developed, and water basins have been successfully used for receiving and storing spent nuclear fuel since the beginning of the nuclear age, 3-e more than 30 years ago. Fuel cladding is expected to remain intact during the period of the proposed interim storage in water basins.[2] This is based upon experience with water basin storage of both Zircaloy and stainless steel clad fuel extending over 20 years and 16 years, respectively, for the two types of cladding. No obvious mechanism of cladding failure under conditions of water basin storage have been identified. Use of water as the storage medium offers the following benefits:

- It is an excellent heat transfer medium for removing decay heat from the fuel, and it provides a substantial heat sink.
- It is a transparent radiation shield that allows visual inspection and direct manipulation of the fuel.
- It provides partial containment of some fission product gases and essentially full containment of any particulate radioactive material that may escape from a fuel assembly.

B.1.1 Facility Description

The water basins are designed to retain their watertight integrity for all credible accidents, including design-basis tornadoes and earthquakes. They are designated as Category I seismic structures, and as such, are designed to 1) resist rupture and excessive loss of water and 2) prevent all massive equipment, such as cranes, etc., from falling into the basins, thus causing damage to the spent fuel during the design-basis earthquake. The water shielding of the fuel also mitigates the effect of tornadic driven missiles.[3]

A schematic representation of the major process steps in a water basin facility is shown in Figure III-1. Figure III-2 is a plot plan for a generic basin storage installation. The major facilities, located within a security fence, include a cask unloading and fuel handling building, an emergency cooling water pond, and the fuel storage basin. Environmental release points are the 45-m (150-ft) high stack, where the airborne effluents are discharged; the cooling tower, where water is evaporated to dissipate heat from the spent fuel and the facility air conditioning system; and the radwaste treatment area, where nonsolid facility wastes are converted to solid wastes for shipment to offsite disposition. At-reactor basin facilities, located within the security fence of the reactor site, would have similar characteristics to those of the ISFS with perhaps some shared auxiliary facilities. The major process areas are described briefly in the following paragraphs. More details about the generic facility and its operations are included in Appendix B.

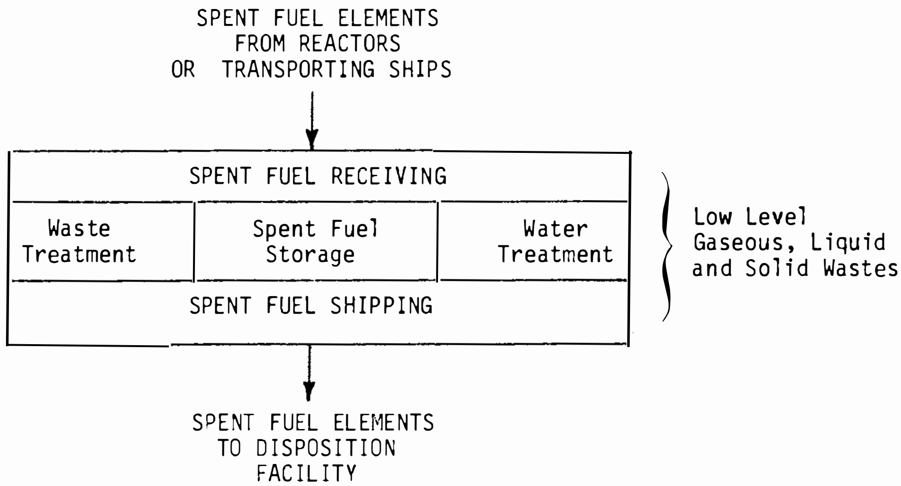

FIGURE III-1. Simplified Schematic of the Storage Basin Process

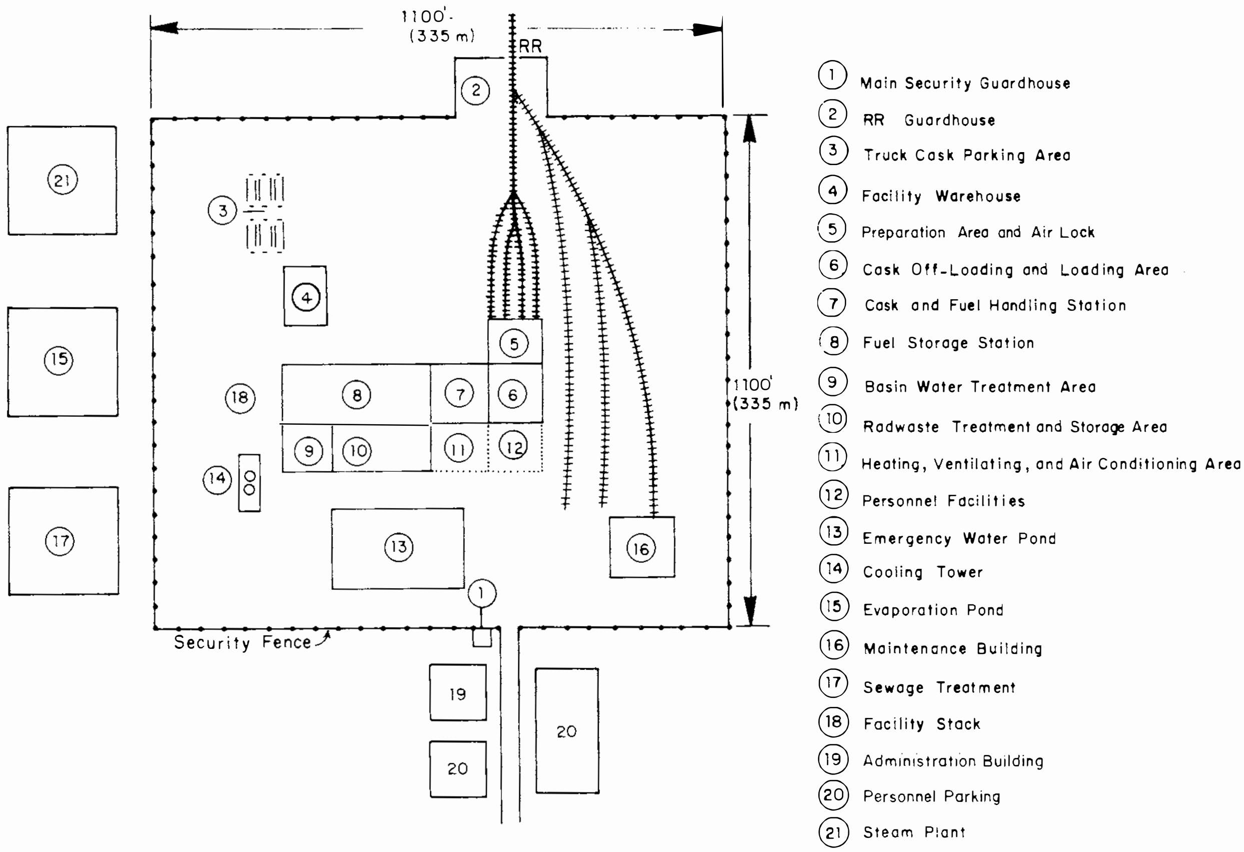

FIGURE III-2. Plot Plan for a Basin Storage Facility for Unpackaged Spent LWR Fuel

Cask-Carrier Handling — Spent fuel is received in the cask-carrier handling area in licensed casks shipped either by rail or truck. Most of these fuel shipments originate from the reactor basins, where the fuel has been cooled for about five years. Descriptions of the casks and carriers can be found in Reference 4. When received, each shipment is identified. The cask is then thoroughly inspected for shipping damage and monitored for radiation. If the inspection indicates that the casks are undamaged, they are unloaded. If damaged, they are repaired in the cask maintenance area. After the casks are emptied and decontaminated, as described below, they are reloaded on the carrier, and inspected to ensure that the return shipment meets DOT regulations.

Cask Processing — After the casks have been removed from the carrier, they are prepared for insertion into the fuel unloading pool. This preparation includes washing the casks to remove road dirt, venting the casks to the off-gas system, and cooling and flushing the casks as required. The water from cask rinsing, flushing, and cooling is collected for treatment.

Underwater Handling and Storage — Cleaned casks are inserted into a deep unloading pool in a vertical position. The water depth in the pool is sufficient to allow vertical unloading of the spent fuel from the casks while still shielding the spent fuel. After the cask is lowered into the pool, the cask lid is removed, and the individual fuel assemblies are transferred to multiple-assembly storage baskets in the pool. All spent fuel in storage baskets is handled by remote control under a minimum of 12 feet of water to shield the operating personnel from the intense radiation emitted from the irradiated fuel. If a fuel assembly leaks significantly, it is placed in a special container to control release of radioactivity during handling and storage.

After all fuel assemblies have been removed and transferred to the storage baskets, the empty cask is inspected to ensure that all fuel and nonfuel items have been removed. The lid is then replaced on the cask. As the cask is removed from the pool, sprays of high velocity demineralized water remove pool water and contamination from the exterior of the cask. When the cask reaches the parapet level, the head bolts are replaced in the lid, and the cask is transferred to the decontamination area.

The storage baskets containing the spent fuel are transferred from the fuel unloading pool to the storage basins and stored underwater in racks fastened to the basin floor. The racks are designed to maintain the spacing of the baskets even during extreme natural phenomena.

Support Operations — The storage basins have support facilities which dissipate the heat, control the quality of water in the pools, ventilate the building, treat the radioactive waste generated, and provide services such as electricity and water.

B.1.2 Waste Management for the Generic Basin Facilities

Releases of radionuclides to the environment from the generic facility are assumed to be through the off-gas system and ventilating air. These release points will be sampled and monitored to measure the amount of releases to the environment. The off-gas system collects gases from cask venting and cool-down and from the radwaste treatment system, and routes it through an off-gas scrubber, an iodine absorber, and high efficiency particulate air (HEPA) filters. The off-gas system is designed to remove most of the iodine and particulates. The ventilating air from the remainder of the basin system is not treated. However, both the treated off-gases and air from the normal building ventilation are released to the environment through the 45-m (150-ft) high stack.

No aqueous releases containing radionuclides are expected from either the ISFS or ARB facilities. The primary cooling system is separated from the secondary cooling system with heat exchangers. This arrangement provides an effective barrier between the environment and potential leaks in the process equipment. The basin water cleanup system incorporates deionization facilities to maintain water radioactivity concentrations at $<2 \times 10^{-4}$ Ci/m^3.

The major volumes of liquid and semiliquid basin wastes requiring treatment are filter sludges, ion-exchange regeneration solutions from the water treatment system, and water-detergent solutions used to decontaminate casks and equipment. These liquids or semiliquids are sent to the evaporator where they are concentrated into a slurry. The water removed during evaporation is released to the atmosphere through the facility stack. The slurry is sent to the waste solidification system for solidification with an agent such as cement or bitumen. The solidified waste will be packaged in 210-L (55-gal) drums and monitored. Waste containing less than 10 nCi transuranic isotopes per gram of wastes will be shipped to a commercial burial ground. The amount of this low-level waste varies with the number of facilities and their storage capacity but is small compared with the amount of low-level wastes generated by reactor operations. Waste containing greater quantities of transuranic isotopes will be stored onsite and shipped to a disposition facility when available. Transuranic contaminated waste is expected to be generated only during facility decommissioning. The amount of transuranic waste will be small compared with the amount of other wastes generated in the fuel cycle and will not increase significantly the amount of storage space required for spent fuel or fuel reprocessing waste.

The solid radioactive wastes include ventilation filters, rags, clothing, plastic, paper, wood, rubber, failed small equipment and similar items. The volume of this material is reduced by incineration and/or compaction. This waste is then packaged in 210-L (55-gal) drums and immobilized before being shipped offsite for disposal.

B.2 Transportation Systems

B.2.1 Existing Cask Systems

NRC licensed shipping casks are available for both truck and rail transport of irradiated spent fuel from current genera- 9-c tion of LWRs. Existing casks could be used for barge transport. Most of the spent fuel casks can be used to transport either PWR or BWR spent fuel by using different fuel baskets. Table III-1 gives information about casks that are currently available or licensed for spent fuel shipments in the United States. These casks are described more fully in Appendix C and Reference 4.

The choice between rail or truck casks for shipping spent fuel is largely determined by availability, costs, convenience, and handling requirements at reactor and storage basins. Rail casks have a significantly larger payload and payload to weight ratio than truck casks. However, truck shipments normally require less turnaround time than rail shipments. Although the newer reactors are providing rail capabilities, about 50% of the reactors now operating in the U.S. or scheduled for completion by the year 1980 do not have rail spurs at the site. By the year 1987, about 30% of the reactors still will not have rail spurs. Many of these reactors without rail spurs can be serviced by intermodal casks,* which require overweight permits for shipping by truck to the nearest rail siding. The assumption is made in this volume that 70% (by weight) of the spent fuel shipped from reactor discharge basins to ISFS facilities is shipped by rail and the rest by truck. Spent fuel transferred from reactor discharge basins to storage 9-c basins on the reactor site is assumed to be moved by truck. Barge service could replace some rail service in the future. Environmental effects would be about the same or slightly less for barge shipments than for rail shipments.[5]

B.2.2 Cask Availability

Casks for spent fuel transport are fabricated by manufacturers who have the capabilities to handle and machine large parts and who have established quality assurance controls required for certi- 9-b fication of casks. Fabrication of spent fuel casks has been curtailed due to lack of firm implementation plans for storage and disposal of spent fuel. In this study, it is assumed that the private or commercial sector will provide the casks as required.

* Casks that are licensed to be moved by truck or rail.

TABLE III-1

Licensed and Available United States Shipping Casks for Current Generation LWR Spent Fuel[a]

Cask Designation	*Number of Assemblies*		*Approximate Loaded Cask Weight, tonne*[b]	*Usual Transport Mode*	*Maximum Heat Removal, kW*
	PWR	*BWR*			
NFS-4[c]	1	2	23	Truck	11.5
NLI 1/2	1	2	22	Truck	10.6
TN-8	3	-	35	Truck[d]	35.5
TN-9	-	7	35	Truck[d]	24.5
IF-300	7	18	79	Rail[e]	76[f]
NLI 10/24	10	24	88	Rail	97[g]

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a. See Reference 7.

b. Skids and other appurtenances are included.

c. The Certificate of Compliance for the NFS-4 cask includes authorization for Nuclear Assurance Corporation to fabricate casks of this design in accordance with the Nuclear Assurance Corporation Quality Assurance Program. Such casks fabricated by NAC will bear a serial number preceded by the prefix NAC.

d. Overweight permit is required by state and local agencies.

e. Truck shipment is authorized for short distances with an overweight permit.

f. Spent fuel loads are limited to a minimum cooling time of 120 days and maximum thermal content of 61.5 kW if shipped with water coolant, or 11.7 kW if shipped with air coolant.

g. Spent fuel loads are limited to a minimum cooling time of 150 days and a maximum thermal content of 70 kW thermal load.

B.2.3 Future Casks

Existing casks have cooling fins and other heat dissipation devices, and in some cases, auxiliary cooling systems. These complex devices have features that are not necessary for transport of spent fuel cooled four years or longer. The average heat load and radiation levels of spent fuel cooled four to five years are substantially lower than that used in existing cask designs which were intended for shipment of fuel to reprocessing facilities immediately after a 0.5-year cooling period. Casks specifically designed for four-year cooled and older spent fuel probably would have increased capacity, lowered cost, increased operating efficiency, and decreased turnaround times. Radiation dose rates exterior to new casks would be within DOT radiation limits. A decision on whether to use new or previously designed casks must involve long-range planning by industry, including any possible plans for spent fuel reprocessing.

B.2.4 Transportation of Wastes

Most solid wastes generated in ISFS or ARB facilities will be shipped to a commercial burial ground site. These wastes normally contain small quantities of fission and activation products and less than 10 nCi of transuranic isotopes per gram of wastes.* These wastes will be reduced in volume by compaction or incineration, packaged, and shipped in containers that meet DOT specifications. The small volume, if any, of ISFS or ARB wastes containing greater concentrations of transuranic elements will be sent to a Federal site for either retrievable interim storage or permanent isolation when available.

B.3 Disposition Facility

In this volume, the environmental effects attributed to spent fuel storage at the disposition facility are limited to the release of radionuclides to the atmosphere after shipping casks carrying the spent nuclear fuel to the disposition facility are vented. Since the nature of the disposition facility is yet to be determined, environmental effects of these releases at the facility were assessed by using reasonable assumptions regarding effluent control, facility siting, and population distribution. These assumptions are discussed in Appendix D.

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* The 10 nCi/g transuranic limit is currently under study and may be revised.

5-a 5-b 5-c A decision on whether to reprocess spent fuel or to treat it as waste for final disposal has not been made pending studies of alternate fuel cycles (see Section II.G) aimed at reducing the risk of nuclear weapons proliferation. Issues associated with such a determination are outside the scope of this EIS since interim storage will not effect either the quantity of spent fuel or options for spent fuel disposal. In Volume 3, the environmental effects of reprocessing and final disposition of foreign fuel in the U.S. were covered to provide an understanding of the possible long-term implications of the U.S. policy for accepting foreign fuel.

C. Description and Evaluation of Alternatives

C.1 Policy Implemented (Alternative 1)

C.1.1 Description

Under the policy implementation alternative (Alternative 1), the U.S. Government would accept title to the irradiated reactor fuel elements considered in this volume. Two options associated with this alternative are depicted schematically in Figure III-3. One option provides centralized interim storage of spent fuel in separate, large, independent spent fuel storage (ISFS) facilities (Option A), and the second one provides decentralized interim storage in smaller ISFS facilities, as required (Option B). In Option A, the U.S. Government would provide the ISFS facilities; in Option B, the U.S. Government may either provide the ISFS facilities or may store its fuel in private basins on a contractual basis.

C C.1.1.1 Centralized Storage (Alternative 1, Option A) (One of DOE's two preferred alternatives)

In Option A (designated Alternative 1A), irradiated reactor fuel is shipped to the U.S. Government ISFS facility starting in the year 1983. Under an early disposition scenario, a disposition
6-b facility becomes available in the year 1985. (It is recognized that the disposition facility will not be available as early as the year 1985.) During the first four years of its operation, the disposition facility operates at only partial capacity, and spent fuel is shipped to both an ISFS facility and to the disposition facility. By the year 1986, spent fuel shipments from the reactors to the ISFS facility and the disposition facility will have reduced inventories at individual reactor discharge basins sufficiently to permit full-core discharge from the reactors. In the year 1988, the disposition facility will begin receiving at full capacity operation, and spent fuel is then shipped directly from the reactors to the facility. Approximately 5400 MTU of spent fuel is shipped to an ISFS facility between the years 1983 and 1988.

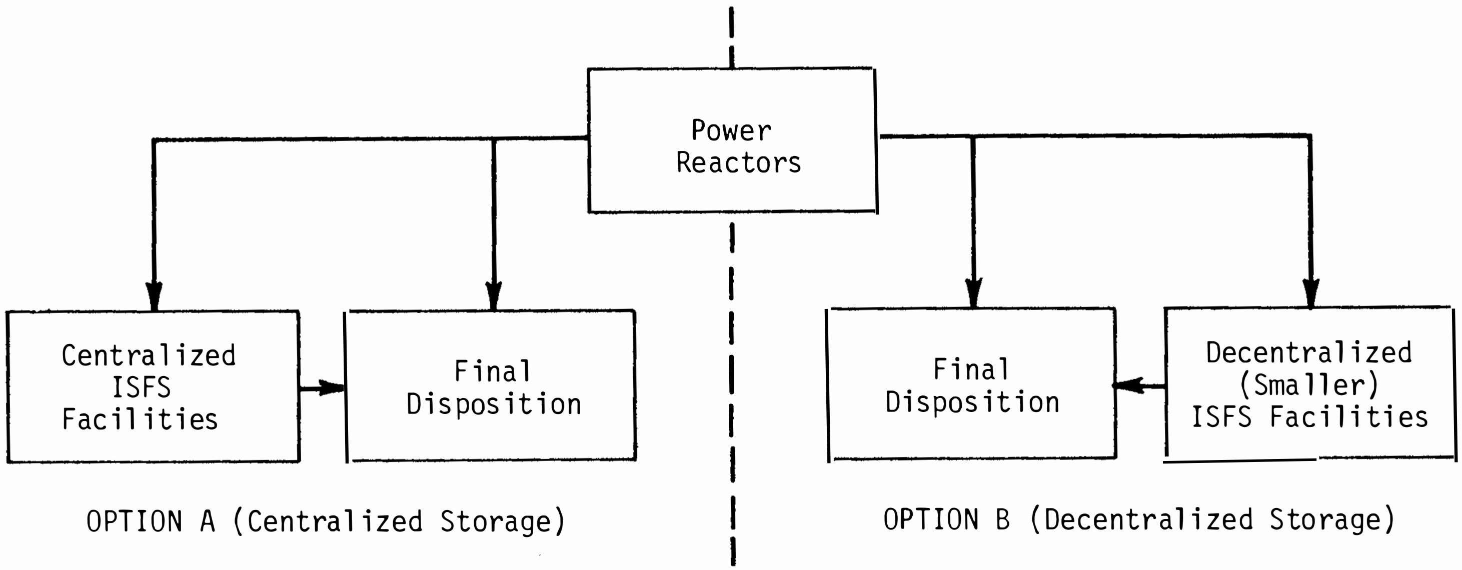

FIGURE III-3. Schematic of Alternative 1 Spent Fuel Flow Path

Environmental effects under Alternative 1A with a 1985 startup of the disposition facility are determined for the following activities:

- Transshipment of about 7100 MTU of spent fuel between reactor basins (1978-2000)
- Construction of a government ISFS facility (1980-1983)
- Shipment of about 5400 MTU of spent fuel from reactor basins to an ISFS facility (1983-1988) and storage in the ISFS facility through the year 1995.
- E Shipment to the disposition facility of about 66,800 MTU of spent fuel from reactor basins (1985-2000) and about 5400 MTU of spent fuel from ISFS facilities (1991-1995)
- Decommissioning of ISFS facility (1996-1997).

Spent fuel movements and inventories are given in Table III-2. 1-e One government ISFS facility is needed under this scenario. This ISFS facility has been assumed to be separate from the disposition facility so that the analysis will conservatively estimate the environmental effects. Collocation would require less transportation and possibly less complicated spent fuel handling facilities.

Potential environmental effects under Alternative 1A are also assessed in the event of a delay in startup of the disposition facility. As shown in Figure III-4, ISFS facility requirements increase sharply from about 5400 MTU as the disposition facility C is delayed (ISFS facility requirements are about 24,000 MTU, 52,000 MTU, 85,000 MTU, 193,000 MTU, and 543,000 MTU of spent fuel as the facility is delayed 5, 10, 15, 25, and 55 years, respectively). The government-operated ISFS facilities are still assumed to begin operation in the year 1983 with capacity added later as needed, for spent fuel transferred to the government before the disposition facility becomes available. By the year 1986, spent fuel shipments from the reactors to ISFS facilities will have reduced inventories at individual reactor basins sufficiently to establish full-core reserve. Detailed calculations of environmental effects of delayed startup of the disposition facility were performed, assuming a C ten-year delay (1995 startup). Appendix E of this volume provides the environmental effect comparison of a delay in startup of the disposition facility until the year 2010. The environmental effects in Appendix E were determined on different fuel flows; therefore, they were not included in this section.

TABLE III-2

Spent Fuel Shipments — Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented — 1985 Startup of Disposition Facility

	ISFS Basins			*Disposition Facility*			
	Fuel Shipments, MTU			*Fuel Shipments, MTU*			
Year	*Reactor to ISFS Basin*	*ISFS Basin to Disposition Facility*	*Inventory, MTU*	*Reactor to Disposition Facility*	*ISFS Basin to Disposition Facility*	*Inventory, MTU*	*Transshipment Between Reactor Basins, MTU*
1978	-	-	0	-	-	0	187
1979	-	-	0	-	-	0	244
1980	-	-	0	-	-	0	160
1981	-	-	0	-	-	0	169
1982	-	-	0	-	-	0	305
1983	970	-	970	-	-	0	287
1984	1,580	-	2,550	-	-	0	349
1985	1,602	-	4,152	100	-	100	380
1986	468	-	4,620	1,600	-	1,700	379
1987	736	-	5,356	1,600	-	3,300	400
1988	-	-	5,356	3,155	-	6,455	400
1989	-	-	5,356	3,368	-	9,823	400
1990	-	-	5,356	3,760	-	13,583	400
1991	-	530	4,826	4,168	530	18,281	300
1992	-	1,410	3,416	4,453	1,410	24,144	300
1993	-	1,300	2,116	4,776	1,300	30,220	300
1994	-	1,300	816	5,026	1,300	36,546	300
1995	-	816	0	5,481	816	42,843	300
1996	-	-	0	5,478	-	48,321	300
1997	-	-	0	5,505	-	53,826	300
1998	-	-	0	5,965	-	59,791	300
1999	-	-	0	6,018	-	65,809	300
2000	-	-	0	6,406	-	72,215	300

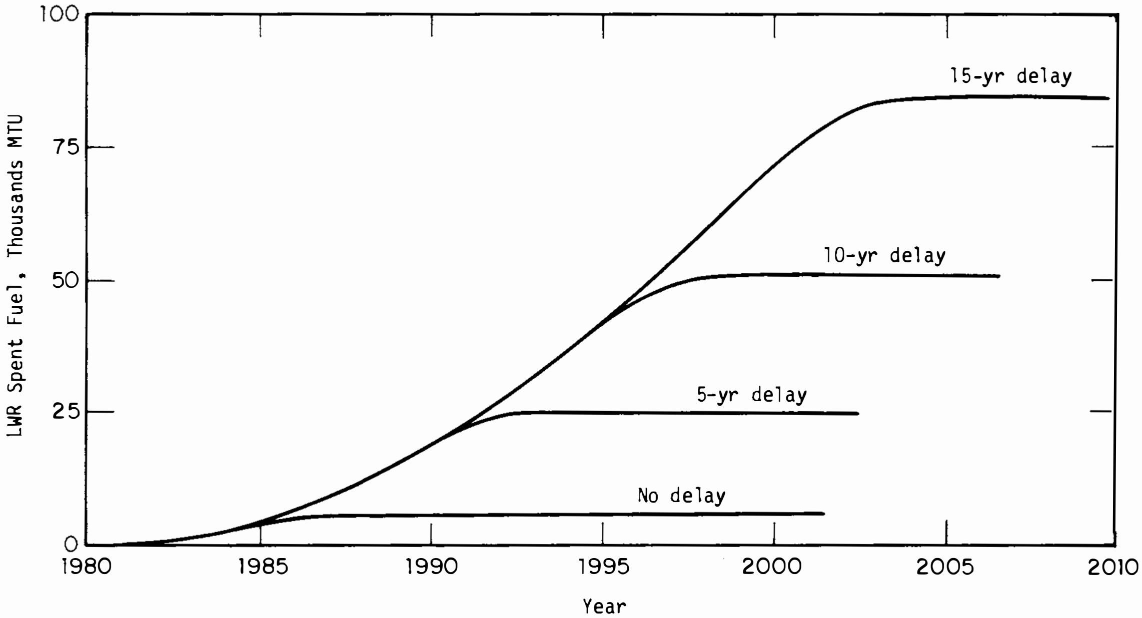

FIGURE III-4. Effects of Delays in Disposition Facility on Government ISFS Facility Capacity Required for Centralized Storage or Decentralized Storage with Full-Core Reserve

Environmental effects of Alternative 1A, with a 1995 startup of the disposition facility, are determined for the following activities:

- Transshipment of about 7100 MTU spent fuel between reactor basins (1978-2000)
- Construction of government ISFS facilities (1980-1998)
- Shipment of about 51,500 MTU spent fuel from reactor basins (1983-1998) and storage through the year 2010
- Shipment to the disposition facility of about 20,700 MTU spent fuel from reactor basins (1995-2000) and about 51,500 MTU spent fuel from ISFS facilities (2004-2010)
- Decommissioning of ISFS facilities (2011-2012).

Spent fuel movements and inventories are given in Table III-3 for startup of the disposition facility in the year 1995. Three ISFS facilities (with 18,000 MTU of spent fuel capacity each) will be required. If the disposition facility begins operation in the year 1990, two ISFS facilities will be required, but, if startup is delayed to the years 2000, 2010, and 2040, then five, 11, and 31 ISFS facilities will be needed. These estimates of storage requirements beyond the year 2000 were developed by assuming that power reactors built after the year 2000 will provide lifetime storage capabilities and therefore will not increase fuel storage requirements. It was also assumed that spent fuel generation rate (that requires storage in ISFS or ARB facilities) will continue at the rate postulated for the latter years of the forecast (1997-2000). The environmental effects for the additional ISFS facilities will be similar to those evaluated for startup of the disposition facility in the years 1985 and 1995.

Appendix E of this volume presents an environmental effects comparison of a delay in startup of the disposition facility until the year 2010. The environmental effects in Appendix E were determined on different fuel flows and different assumptions on new reactors spent fuel storage capability and therefore were not included in this section. The fuel flows in Appendix E are more current and use less ISFS storage capacity than those used in this section.

A delay in the disposition facility startup increases the time spent fuel will need to be stored. Present fuel technology indicates that spent fuel may be safely stored in water basins for at least 30 years without significant cladding deterioration.[6] Studies to determine the safe storage life of spent fuel in water basins are underway at various laboratories and basin facilities. If new information developed by these studies or experience in actual storage indicates a lifetime of the spent fuel less than the intended storage time, sufficient lead time will be available to encapsulate the fuel being stored before significant fuel failure causes increased environmental effects.

TABLE III-3

Spent Fuel Shipments — Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented — 1995 Startup of Disposition Facility

Year	*Government ISFS Basin Fuel Shipments, MTU*		*Disposition Facility Fuel Shipments, MTU*		*Transshipment Between Reactor Basins, MTU*
	Reactor to ISFS Basins	*Inventory*	*Reactor to Disposition Facility*	*Inventory*	
1978	-	-	-	-	187
1979	-	-	-	-	244
1980	-	-	-	-	160
1981	-	-	-	-	169
1982	-	-	-	-	305
1983	970	970	-	-	287
1984	1,580	2,550	-	-	349
1985	1,702	4,252	-	-	380
1986	2,068	6,320	-	-	379
1987	2,336	8,656	-	-	400
1988	3,155	11,811	-	-	400
1989	3,368	15,179	-	-	400
1990	3,760	18,939	-	-	400
1991	4,168	23,107	-	-	300
1992	4,453	27,560	-	-	300
1993	4,776	32,336	-	-	300
1994	5,026	37,362	-	-	300
1995	5,381	42,743	100	100	300
1996	3,878	46,621	1,600	1,700	300
1997	3,905	50,526	1,600	3,300	300
1998	965	51,491	5,000	8,300	300
1999	-	51,491	6,018	14,318	300
2000	-	51,491[a]	6,406	20,724	300

a. Shipped to disposition facility during the years 2004 to 2010.

C.1.1.2 Decentralized Storage (Alternative 1, Option B)

In Option B (designated Alternative 1B), irradiated reactor fuel is retained in reactor storage basins consistent with maintaining reserve basin capacities equivalent to one scheduled annual discharge or full-core discharge from the reactors. Additional storage requirements are met by construction of small decentralized private (or government) ISFS facilities and operated under one of two suboptions.

In the first suboption (designed Alternative 1B-1 and one of DOE's two preferred alternatives), spent fuel shipments from the reactor to the ISFS facilities and the disposition facilities are assumed to be sufficient to reduce inventories at individual reactor discharge basins to permit full-core discharge by the year 1985. Alternative 1B-1 is similar to Alternative 1A described in Section III.C.1.1.1 except that smaller ISFS facilities are assumed in that alternative; thus, more ISFS facilities will be required.

In the second suboption (designated Alternative 1B-2), shipments from individual reactor discharge basins to disposition facilities are assumed to be sufficient to maintain capacity for one annual discharge until full-core reserve is established in the year 1991.

Environmental effects under Alternative 1B-2 (1985 startup of the disposition facility) are determined for the following activities:

- Transshipment of about 7100 MTU spent fuel between reactor basins (1978-2000)
- Construction of ISFS facilities (1980-1983)
- Shipment of about 500 MTU spent fuel from reactor basins to one ISFS facility (1983-1986) and storage through the year 1992
- Shipment to the disposition facility of about 71,700 MTU spent fuel from reactor basins (1985-2000) and about 500 MTU spent fuel from ISFS facility (1991-1992)
- Decommissioning of ISFS facility (1993-1994).

Spent fuel movements and inventories under Alternative 1B-2 with a 1985 startup of the disposition facility are given in Table III-4. One ISFS facility with a capacity of about 500 MTU 6-b will be required to maintain discharge capability. (It is recognized that startup of the disposition facility probably will not be achieved as early as the year 1985.)

Potential environmental effects under Alternative 1B-2 were also assessed for delayed startup of the disposition facility. As shown in Figure III-5, ISFS facility requirements increase from about 500 MTU for 1985 disposition facility startup to about C 8000 MTU, 24,000 MTU, and 52,000 MTU of spent fuel as the facility is delayed 5, 10, and 15 years, respectively. If the disposition facility is delayed 25 and 55 years, the ISFS facility requirements would be 158,000 and 508,000 MTU, respectively. These increases are not as great as in Alternative 1B-1 because larger inventories are maintained in the reactor discharge storage basins in Alternative 1B-2. As indicated in the discussion in Section C.1.1.1, Appendix E of this volume provides an environmental effects comparison for delay in startup of the disposition facility until the year 2010.

ISFS facilities for Alternative 1B-2 are assumed to begin operation in the year 1983 with capacity added later, as needed, for spent fuel transferred to the government before final disposition can be implemented. The size of these basin facilities C is limited to 6000 MTU spent fuel. Spent fuel shipments are accelerated from reactor discharge basins after the disposition facility becomes available; but, for delayed disposition facility startup of ten years or greater, inventories at individual reactor basins will not be reduced sufficiently to permit full-core discharge until after the year 2000. Detailed calculations of environmental effects of delayed startup of the disposition facility are made, assuming a ten-year delay (1995 startup).

Environmental effects of Alternative 1B-2 (annual discharge capability) with a 1995 startup of the disposition facility, are determined for the following activities:

- Transshipment of about 7200 MTU spent fuel between reactor basins (1978-2000)
- Construction of ISFS facilities (1980-1997)
- Shipment of about 24,000 MTU spent fuel from reactor basins to ISFS facilities (1983-1997) and storage until after the year 2000
- Shipment to the disposition facility of about 48,200 MTU spent fuel from reactor basins (about 21,000 MTU spent fuel through the year 2000), and about 24,000 MTU spent fuel from ISFS facilities (after the year 2000)
- Decommissioning of ISFS facilities (2012-2013).

TABLE III-4

Spent Fuel Shipments — Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A) — 1985 Startup of Disposition Facility

	Private or Government ISFS Basins			*Disposition Facility*			
	Fuel Shipments, MTU			*Fuel Shipments, MTU*			
Year	*Reactor to ISFS Basin*	*ISFS Basin to Disposition Facility*	*Inventory, MTU*	*Reactor to Disposition Facility*	*ISFS Basin to Disposition Facility*	*Inventory, MTU*	*Transshipments Between Reactor Basins, MTU*
1978	-	-	-	-	-	-	187
1979	-	-	-	-	-	-	244
1980	-	-	-	-	-	-	160
1981	-	-	-	-	-	-	169
1982	-	-	-	-	-	-	305
1983	56	-	56	-	-	-	287
1984	146	-	202	-	-	-	349
1985	261	-	463	100	-	100	380
1986	-	-	463	1,600	-	1,700	379
1987	-	-	463	1,600	-	3,300	400
1988	-	-	463	4,200	-	7,500	400
1989	-	-	463	5,000	-	12,500	400
1990	-	-	463	5,976	-	18,476	400
1991	-	263	200	4,168	263	22,907	300
1992	-	200	-	4,453	200	27,560	300
1993	-	-	-	4,776	-	32,336	300
1994	-	-	-	5,026	-	37,362	300
1995	-	-	-	5,481	-	42,843	300
1996	-	-	-	5,478	-	48,321	300
1997	-	-	-	5,505	-	53,826	300
1998	-	-	-	5,965	-	59,791	300
1999	-	-	-	6,018	-	65,809	300
2000	-	-	-	6,406	-	72,215	300

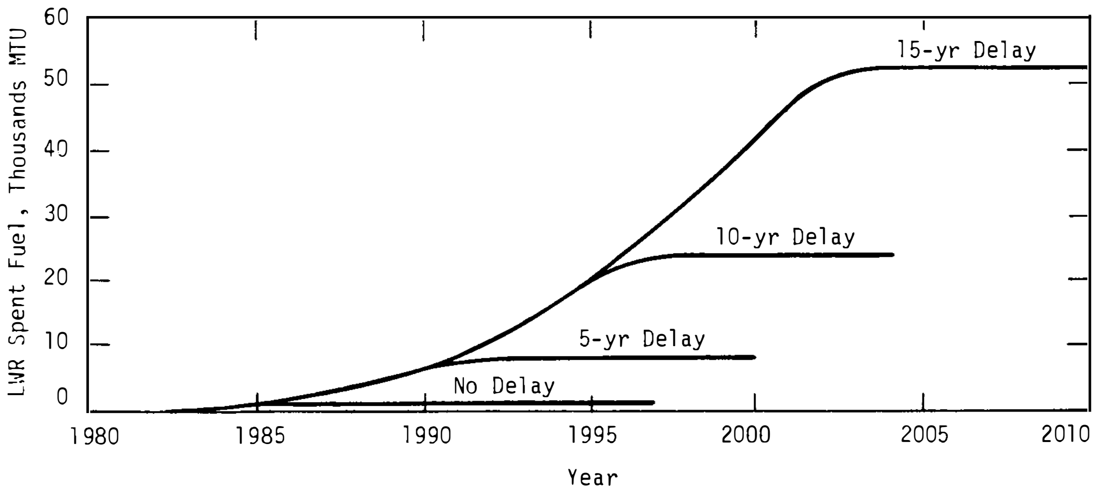

FIGURE III-5. Effects of Delays in Disposition on Private or Government ISFS Facility Capacity Required for Decentralized Storage with Annual Discharge Capabilities

Detailed spent fuel movements and inventories under Alternative 1B-2 are given in Table III-5 for a 1995 startup of the disposition facility. Four ISFS facilities (with 6000 MTU of spent fuel capacity each) will be required. Two ISFS facilities will be required for 1990 startup, nine for 2000 startup, 27 for 2010 startup, and 85 for 2025 startup (see discussion on delayed startup beyond 2000 in Section C.1.1.1 and Appendix E).

TABLE III-5

Spent Fuel Shipments — Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A) — 1995 Startup of Disposition Facility

	Private or Government ISFS Basins Fuel Shipments, MTU		*Facility Disposition Fuel Shipments, MTU*		
Year	*Reactor to ISFS Basin*	*Inventory*	*Reactor to Facility Disposition*	*Inventory*	*Transshipments Between Reactor Basins, MTU*
1978	-	-	-	-	187
1979	-	-	-	-	244
1980	-	-	-	-	160
1981	-	-	-	-	169
1982	-	-	-	-	305
1983	56	56	-	-	287
1984	146	202	-	-	349
1985	361	563	-	-	380
1986	531	1,094	-	-	379
1987	1,002	2,096	-	-	400
1988	1,362	3,458	-	-	400
1989	1,585	5,043	-	-	400
1990	1,717	6,760	-	-	400
1991	2,006	8,766	-	-	400
1992	2,345	11,111	-	-	400
1993	2,523	13,634	-	-	400
1994	2,953	16,587	-	-	400
1995	3,088	19,675	100	100	400
1996	1,883	21,558	1,600	1,700	400
1997	2,413	23,971	1,600	3,300	400
1998	-	23,971	5,000	8,300	100
1999	-	23,971	6,018	14,318	100
2000	-	23,971[a]	6,406	20,724[b]	100

a. Shipped to the disposition facility after year 2000.

b. An additional 27,500 MTU spent fuel in reactor discharge basins shipped to the disposition facility after the year 2000.

C.1.2 Evaluation of Environmental Effects — Alternative 1A (Centralized Storage) and Alternative 1B-1 (Decentralized Storage with Full-Core Reserve)

C.1.2.1 Use of Natural Resources

Resource commitments for materials and energy under Alternatives 1A and 1B-1 are given in Table VI-1. The most significant increases in consumption if the disposition facility is delayed until the year 1995 are given below.

In comparison to the 1985 startup of the disposition facility,

- Coal consumption increases about 15-fold to 6 million tonnes.
- Electricity consumption increases about 15-fold to 1×10^3 MW-yr.
- Manpower use increases 45 million man-hours to 85 million man-hours.
- Chromium and nickel consumption increases because use of stainless steel increases about 2×10^4 tonnes to 3×10^4 tonnes; however, most of the stainless steel can be recycled, if required.
- Steel consumption increases about 5-fold to 1×10^5 tonnes, primarily because of construction of additional ISFS facilities.

C.1.2.2 Radiological Effects of Normal Operations

Sources of Radiological Effects During Normal Operations — Transport of spent reactor fuel results in some direct external radiation dose to the public along the route of transport, as well as to transport workers. During transport of spent fuel, a small percentage of the fuel elements may suffer cladding failure, resulting in release of radioactive material to the cask cavity. In this volume, it is assumed that none of this radioactive material is released to the environment during normal transportation operations. However, a small fraction would be released through the facility ventilation systems during cask unloading at the ISFS facilities and at the disposition facility. This environmental release of radioactivity results in a small population radiation dose commitment.

Handling, storage, and retrieval of spent fuel at ISFS facilities are assumed to result in an additional small number of fuel cladding failures. These failures also result in the release of a small amount of radioactive material through the ventilation system at the ISFS facility.

The radionuclides that are assumed to be released to the atmosphere under Alternative 1A (policy implemented with centralized storage) and Alternative 1B-1 (policy implemented with decentralized storage with full-core reserve) are shown in Table III-6. Releases are shown for a 1985 startup of the disposition facility and for facility startup in the year 1995 (ten-year delay). The list is restricted to radionuclides expected to contribute significantly to the population dose. Releases from cask ventings and normal operations at ISFS facilities are discussed more fully in Appendices B, C, and D.

Population Doses — Population doses from environmental release of radioactivity under Alternatives 1A and 1B-1 are calculated for the local (80-km radius, see Appendix A for additional description of local environment), United States, and world populations. Effects from long-lived nuclides for a 100-year period after the end of the study (until the year 2100) are included to provide an assessment of the impact of persistent nuclides. The population doses from transport of fuel, from normal releases of radioactivity during ISFS facility operations and from cask ventings (released through the receiving facility ventilation system) are summarized in Table III-7. The whole body dose to the world population is 1300 man-rem if the disposition facility starts up in the year 1985; and the dose increases to 16,600 man-rem if the disposition facility is delayed ten years. To place this population dose in perspective, it is a very small fraction of the exposure to the world population from natural radiation sources in the same period (about 2×10^{11} man-rem).

The maximum whole body dose commitment to an individual in the offsite population in any year is expected to be about three mrem if the disposition facility begins operation in the year 1985; it is expected to increase to about five mrem if the facility is delayed ten years. This "maximum" individual is assumed to reside continuously at the site boundary of the ISFS facility at the point of highest atmospheric concentration. For perspective, the maximum dose commitment to an individual from basin operations is small compared with the exposure from natural radiation sources that averages 100 mrem/yr in the entire world.

TABLE III-6

Radionuclides Released to the Atmosphere from Storage Basin Operations — Centralized Storage (Alternative 1A) and Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented

	Cumulative Release, Curies					
	Disposition Facility Startup, 1985			*Disposition Facility Startup, 1995*		
Nuclide[a]	*Cask Venting*	*ISFS Operations*	*Total*	*Cask Venting*	*ISFS Operations*	*Total*
^{3}H	2.2×10^{0}	9.7×10^{1}	9.9×10^{1}	2.1×10^{1}	8.1×10^{2}	8.3×10^{2}
^{14}C	1.1×10^{-2}	5.3×10^{-1}	5.4×10^{-1}	1.0×10^{-1}	6.1×10^{0}	6.2×10^{0}
^{85}Kr	1.4×10^{3}	6.2×10^{4}	6.3×10^{4}	1.4×10^{4}	5.1×10^{5}	5.2×10^{5}
^{129}I	2.6×10^{-6}	1.0×10^{-3}	1.0×10^{-3}	1.9×10^{-5}	9.6×10^{-3}	9.6×10^{-3}
^{55}Fe	-	6.9×10^{-2}	6.9×10^{-2}	-	1.1×10^{0}	1.1×10^{0}
^{60}Co	-	9.0×10^{-2}	9.0×10^{-2}	-	1.3×10^{0}	1.3×10^{0}
^{90}Sr	3.8×10^{-5}	1.8×10^{-2}	1.8×10^{-2}	3.7×10^{-4}	2.7×10^{-1}	2.7×10^{-1}
^{134}Cs	3.4×10^{-5}	2.1×10^{-1}	2.1×10^{-1}	3.2×10^{-4}	3.2×10^{0}	3.2×10^{0}
^{137}Cs	5.0×10^{-5}	1.4×10^{0}	1.4×10^{0}	5.1×10^{-4}	2.1×10^{1}	2.1×10^{1}

a. Nuclides expected to contribute significantly to the dose from ISFS Basin operations. Radionuclides released during cask venting account for a small part of the total dose and are discussed more fully in Appendices B, C, and D.

TABLE III-7

Population Dose Commitment for Storage Basin Operations — Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented

	Population Dose, man-rem[a]							
	Disposition Facility Startup, 1985				*Disposition Facility Startup, 1995*			
Organ	*Local, 80-km radius*	*U.S., Less Local*	*World, Less U.S.*	*Total for Entire Period*	*Local, 80-km radius*	*U.S., Less Local*	*World, Less U.S.*	*Total for Entire Period*
Whole Body[b]								
Transportation - external gamma	17	200	-	220	24	190	-	210
Releases during cask venting	3	4	17(10)	24(17)	2	4	29(14)	35(20)
ISFS - Normal operations	550	440	55(31)	1050	8600	7100	720(380)	16,400(16,100)
Total	570	640	72(41)	1300	8600	7300	740(390)	16,600(16,100)
Thyroid[c]								
Releases during cask venting	58	54	-	110	62	57	-	120
ISFS - Normal operations	4	4	-	8	44	37	-	81
Total	62	58	-	120	110	94	-	200
Bone[c]								
Releases during cask venting	<1	<1	-	<1	<1	<1	-	<1
ISFS - Normal operations	68	54	-	120	1000	830	-	1,800
Total	68	54	-	120	1000	830	-	1,800
Lung[c]								
Releases during cask venting	<1	<1	19	19	<1	<1	24	24
ISFS - Normal operations	≤1	1	19	20	6	12	370	390
E *Total*	<1	1	38	39	6	12	390	410
Red Marrow[c]								
Releases during cask venting	<1	<1	18	18	<1	<1	29	29
ISFS - Normal operations	≤1	2	52	54	5	17	760	780
E *Total*	<1	2	70	72	5	17	790	810

a. Continued effects of releases included for a 100-year period after end of operations.

b. Gonad doses shown in parentheses when gonad doses differ from whole body doses.

c. Doses in addition to organ dose from whole body irradiation.

Population Health Effects — Health effects calculated from the world population dose for the period of operation and the next 100 years are shown in Table III-8. The health effects were calculated with the linear dose-effect relationships derived from the BEIR[7] report by the EPA.[8,9] No threshold dose is assumed for health effects. The total number of health effects in the world population under these assumptions is about one if the disposition facility begins operation in the year 1985 and increases to about ten if the facility is delayed ten years. An expanded discussion of the health effects is included in Appendix B of this volume.

Occupational Exposure — Federal regulations[10] require that the occupational external dose to an individual not exceed five rem/yr or a cumulative value of 5(N-18) rem, where N is the present age of the worker. Estimates of personnel exposure anticipated in nuclear facilities often assume an average personnel dose (not including administrative and other personnel who are not exposed to occupational radiation) of 40% of the maximum, or two rem/yr average for a five rem/yr limit.[11] It is anticipated that allowable personnel exposure will be reduced through regulatory incorporation of "as low as reasonably achievable" limits. Although such limits have not been determined for spent fuel storage facilities, the criterion of one rem/yr maximum exposure required of new DOE plutonium facilities[12] is assumed to apply. The average exposure of radiation workers is then conservatively* assumed to be 40% of the one rem limit, or 400 mrem/(year-person). Personnel exposure is assumed to be limited by the use of shielding and procedural controls, not by supplementing the work force.

The occupational dose to the work force under Alternative 1A is expected to be about 1200 man-rem and about 1100 man-rem under Alternative 1B-1 if the disposition facility begins operation in the year 1985, as shown in Table III-9. If the disposition facility is delayed ten years (1995 startup), the occupational dose is expected to increase to 5000 man-rem for Alternative 1A and to 8900 man-rem for Alternative 1B-1.

7-b * The assumptions used for estimating occupational exposure overestimate dose, based upon limited experience at the GE/Morris, IL, fuel storage facility and are used to ensure that occupational health effects are not underestimated.

TABLE III-8

Calculated Population Health Effects for Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented

	Facility or Process	*Population Health Effects*[a] *Disposition Facility Startup* 1985	1995
E	Transportation	1.3×10^{-1}	1.3×10^{-1}
	Cask Venting	2.1×10^{-2}	2.4×10^{-2}
	ISFS Operations[b]	6.3×10^{-1}	9.9×10^{0}
	Total	7.8×10^{-1}	1.0×10^{1}

a. Health effects calculated with EPA dose-effect factors for exposures during the period of operation and for the next 100 years.

C *b.* Includes somatic effects from Table B-14 and genetic effects from Table B-16.

TABLE III-9

Occupational Doses for Facility Operation

	Whole Body Dose, man-rem[a]			
	Centralized Storage — Policy Implemented (Alternative 1A)		*Decentralized Storage with Full-Core Reserve — Policy Implemented (Alternative 1B-1)*	
	Disposition Facility Startup		*Disposition Facility Startup*	
Facility or Process	*1985*	*1995*	*1985*	*1995*
Transportation	620	620	620	620
ISFS	570	4400	430	8290
Total	1200	5000	1050	8900

a. For period of operation.

C.1.2.3 Occupational Accidents

Occupational accidents under Alternatives 1A and 1B-1 are
7-j expected to result in about 11 deaths in the work force for 1985
startup of the disposition facility. The comparable number of
occupational deaths for 1995 startup of the disposition facility
7-j are 14 deaths for Alternative 1A and 17 deaths for Alternative
1B-1. Details on development of these values can be found in
Appendix B. A large number of the accidental deaths (about 10)
occur during truck transport of the spent fuel. For perspective,
the expected 11 to 17 deaths from occupational accidents over the
entire period of this alternative can be compared with the 12,500
deaths in the year 1976 from occupational accidents in the U.S.

C.1.3 Evaluation of Environmental Effects of Alternative 1B-2 (Decentralized Storage with Discharge Capability)

C.1.3.1 Use of Natural Resources

Resource commitments for materials and energy under Alternative 1B-2 (policy implemented with decentralized storage while maintaining discharge capability) are given in Table VI-1. The most significant increases in consumption if the disposition facility is delayed from the year 1985 until the year 1995 are given below.

In comparison to the 1985 startup of the disposition facility,

- Coal consumption increases about 50-fold to 3 million tonnes.
- Electricity consumption increases about 60-fold to 5×10^2 MW-yr.
- Manpower use increases 39 million man-hours to 76 million man-hours.
- Chromium and nickel consumption increase because use of stainless steel increases about 6-fold to 2×10^4 tonnes; however, most of the stainless steel can be recycled.
- Steel consumption increases about 10-fold to 6×10^4 tonnes, primarily because of construction of additional ISFS facilities.

C.1.3.2 Radiological Effects of Normal Operations

Sources of Radiological Effects During Normal Operations — The radionuclides that are assumed to be released to the atmosphere under Alternative 1B-2 (decentralized storage while maintaining discharge capability) are shown in Table III-10. Releases are shown for 1985 startup of the disposition facility and for a 1995 startup (ten-year delay). Releases from cask ventings and normal operations at ISFS facilities are discussed more fully in Appendices B, C, and D.

Population Doses — The doses calculated for local, U.S., and world populations during the period of operation and the next 100 years are given in Table III-11. The doses result from transport of fuel, cask ventings, and normal operations at ISFS facilities. The whole body dose to the world population increases from 320 man-rem to 9200 man-rem if the disposition facility is delayed ten years. In either case, this dose is a very small fraction of the exposure to the world population from natural radiation sources in the same period (about 2×10^{11} man-rem).

The maximum whole body dose commitment to an individual in the offsite population in any year is expected to be 0.3 mrem if the disposition facility begins operation in the year 1985 and is expected to increase to about two mrem if the facility is delayed ten years. For perspective, the maximum dose commitment to an individual from basin operations is small compared with the exposure from natural radiation sources that averages 100 mrem/yr in the entire world.

Population Health Effects — Health effects calculated from the world population dose for the period of operation and the next 100 years are shown in Table III-12. They were calculated as described in Section III C.1.2.2. The total number of health effects in the world population under these assumptions is less than one if the disposition facility begins operation in the year
E 1985 and increases to about six if the facility is delayed ten years.

Occupational Radiation Exposure — The occupational radiation dose to the work force under Alternative 1B-2 was also calculated as described in Section III C.1.2.2. It is expected to be about 800 man-rem if the disposition facility begins operation in the year 1985, as shown in Table III-13. If the disposition facility is delayed ten years (1995 startup), the occupational dose is expected to increase to 4300 man-rem.

TABLE III-10

Radionuclides Released to the Atmosphere from Storage Basin Operations — Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)

	Release During Entire Period, Curies					
	Disposition Facility Startup, 1985			*Disposition Facility Startup, 1995*		
Nuclide[a]	*Cask Venting*	*ISFS Operations*	*Total*	*Cask Venting*	*ISFS Operations*	*Total*
^{3}H	1.9×10^{-1}	8.8×10^{0}	9.0×10^{0}	9.8×10^{0}	3.7×10^{2}	3.8×10^{2}
^{14}C	9.2×10^{-4}	4.6×10^{-2}	4.7×10^{-2}	4.7×10^{-2}	2.4×10^{0}	2.4×10^{0}
^{85}Kr	1.2×10^{2}	5.4×10^{3}	5.5×10^{4}	6.3×10^{3}	2.4×10^{5}	2.5×10^{5}
^{129}I	1.7×10^{-7}	8.5×10^{-5}	8.5×10^{-7}	8.8×10^{-6}	4.4×10^{-3}	4.4×10^{-3}
^{55}Fe	-	5.6×10^{-3}	5.6×10^{-3}	-	5.8×10^{-1}	5.8×10^{-1}
^{60}Co	-	7.0×10^{-3}	7.0×10^{-3}	-	7.2×10^{-1}	7.2×10^{-1}
^{90}Sr	3.3×10^{-6}	1.4×10^{-3}	1.4×10^{-3}	1.7×10^{-4}	1.5×10^{-1}	1.5×10^{-1}
^{134}Cs	2.9×10^{-6}	1.7×10^{-2}	1.7×10^{-2}	1.5×10^{-4}	1.7×10^{0}	1.7×10^{0}
^{137}Cs	4.5×10^{-6}	1.1×10^{-1}	1.1×10^{-1}	2.4×10^{-4}	1.1×10^{1}	1.1×10^{1}

a. Nuclides expected to contribute significantly to the population dose from ISFS Basin operations. Radionuclides released during cask venting account for a small part of the total dose and are discussed more fully in Appendices B, C, and D.

TABLE III-11

Population Dose Commitment for Storage Operations — Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)

	Population Dose, man-rem[a]							
	Disposition Facility Startup, 1985				*Disposition Facility Startup, 1995*			
Organ	*Local, 80-km Radius*	*U.S., Less Local*	*World, Less U.S.*	*Total for Entire Period*	*Local, 80-km Radius*	*U.S., Less Local*	*World, Less U.S.*	*Total for Entire Period*
Whole Body[b]								
Transportation - External Gamma	14	200	-	210	19	180		200
Releases During Cask Venting	2	3	19(11)	24(16)	2	4	23(11)	29(17)
ISFS - Normal Operations	42	34	5(2)	81(76)	4700	4000	300(160)	9000(8800)
Total	58	240	24(13)	320(300)	4700	4200	330(170)	9200(9000)
Thyroid[c]								
Releases During Cask Venting	58	54	-	110	63	58	-	120
ISFS - Normal Operations	<1	<1	-	<1	20	17	-	37
Total	58	54	-	110	83	75	-	160
Bone[c]								
Releases During Cask Venting	<1	<1	-	<1	<1	<1	-	<1
ISFS - Normal Operations	6	4	-	10	600	480	-	1100
Total	6	4	-	10	600	480	-	1100
Lung[c]								
Releases During Cask Venting	<1	<1	17	17	<1	<1	18	18
ISFS - Normal Operations	<1	<1	4	4	2	8	230	240
Total	<1	<1	21	21	2	8	250	260
Red Marrow[c]								
Releases During Cask Venting	<1	<1	16	16	<1	<1	24	24
ISFS - Normal Operations	<1	<1	5	5	2	7	330	340
Total	<1	<1	21	21	2	7	350	360

a. Continued effects of releases are included for a 100-year period after end of operations.

b. Gonad doses shown in parentheses when gonad doses differ from whole body doses.

c. Doses in addition to organ dose from whole body irradiation.

TABLE III-12

Calculated Population Health Effects for Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)

	Population Health Effects[a]	
	Disposition Facility Startup	
Facility or Process	*1985*	*1995*
E Transportation	1.3×10^{-1}	1.2×10^{-1}
Cask Venting	2.1×10^{-2}	2.8×10^{-2}
ISFS Operations[b]	4.8×10^{-2}	5.5×10^{0}
Total	2.0×10^{-1}	5.6×10^{0}

a. Health effects calculated with EPA dose-effect factors for exposures during the period of operation and for the next 100 years.

C *b.* Includes somatic effects from Table B-14 and genetic effects from Table B-16.

TABLE III-13

Occupational Doses for Decentralized Storage with Discharge Capabilities - Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)

	Whole Body Dose, man-rem[a]	
	Disposition Facility Startup	
Facility or Process	*1985*	*1995*
Transportation	610	550
ISFS	180	3700
Total	790	4300

a. For period of operation.

C.1.3.3 Occupational Accidents

Occupational accidents under Alternative 1B-2 are expected
7-j to result in about 11 deaths in the work force for 1985 startup of the disposition facility or 14 deaths for a ten-year delay in facility startup. Details on development of these values can be found in Appendix B. For perspective, the expected 11 deaths from occupational accidents in this alternative can be compared
E with the 12,500 deaths in 1976 from occupational accidents in the U.S.

C.2 Policy Not Implemented (Alternative 2)

C.2.1 Description

In Alternative 2, the policy not implemented case, the U.S. Government is assumed to take no action in resolving the uncertainties associated with interim storage of spent nuclear
2-a fuel. In this case, it is assumed that utilities would take
2-d appropriate actions to avoid forced shutdowns; therefore,
4-a shutdown effects are not included. This assumption was made because of the unacceptable and severe economic burden on the users of an alternative source of power in place of the power that would have been generated by the shutdown reactor.

Although it has been assumed that utilities can provide adequate storage to avoid reactor shutdowns if the policy is not implemented, some isolated shutdowns could occur due to technical, institutional or regulatory reasons. The generic impact of a reactor shutdown due to insufficient storage is analyzed in NUREG-0575[1]. This analysis concluded that it was "economically and environmentally preferable" to take the "necessary measures to alleviate spent fuel capacity shortfalls rather than to generate power with coal fired power plants." The analysis also determined that the principal unavoidable adverse environmental impacts associated with coal fired and nuclear power generation are the impact on occupational and public exposure to pollutants (including radiation) and land use for construction and mining. Table III-14 obtained from NUREG-0575 shows a comparison of the major environmental impacts of power generation from nuclear and coal fired power plants. The reactor shutdowns described in this EIS are a small increment of the total generated capacity and would result in the purchase of more costly power but no new power plant construction. The construction and land requirements shown in Table III-14 do not apply to generating plant operations which is the action discussed in this EIS. A more detailed comparison of the applicable environmental impacts (mortality) between nuclear and replacement power generation is provided in Table III-15 (also obtained from NUREG-0575[1]).

2-a 2-d 4-a DOE has consistently been of the opinion that implementation of the Spent Fuel Storage Policy would not discourage the initiative of utilities for expanding storage capacity in existing reactor discharge basins. Utilities are expected to first optimize storage capacity in their existing reactor discharge basins since this is the most economic action available. That assumption is supported by NRC licensing activity[1] in that as of December 31, 1978, 65 of the 69 then-operating reactors had either been licensed to expand their design spent fuel storage capability by an average factor of about three, or were seeking such licensing.

C

TABLE III-14

Estimated Environmental Costs for One-Year Operation of 1000-MWe Generating Plant[a]

Type of Impact	*Magnitude* *Nuclear*	*Coal*
Disturbed land (acres)		
New construction	<0.1	~30
Mining	~60	~90
General construction impacts[b]	~0.5	~30
Mortality	~1	~40

a. Table obtained from Final Generic Environmental Impact Statement, Handling and Storage of Spent Light Water Power Reactor Fuel.[1] Report NUREG-0575, U.S. Nuclear Regulatory Commission, Washington, DC (August 1979).

b. In arbitrary units, assumed to be proportional to construction cost.

TABLE III-15

Comparison of Potential Excess Mortality of Nuclear versus Coal Power Generation per 0.8 GWY(e)[a]

Fuel Cycle Component	*Nuclear*	*Coal*
Resource recovery (mining, drilling, etc.)	0.32	0.3-8.0
Processing	0.073-1.1	10
Power generation	0.13-0.3	3-100
Fuel storage	~0	~0
Transportation	0.01	1.2
Reprocessing	0.059-0.065	-
Waste management	0.001	~0
Totals	0.57-1.7	15-120

a. Table obtained from Final Generic Environmental Impact Statement, Handling and Storage of Spent Light Water Power Reactor Fuel.[1] Report NUREG-0575, U.S. Nuclear Regulatory Commission, Washington, DC (August 1979).

2-a 2-d 4-a Capacity, in addition to that provided by optimum utilization of existing reactor discharge basins, will be required by some reactors. This capacity may be provided by transshipment. This option may not be available to some of the smaller utilities and may be precluded by institutional reasons for others. Other options available include construction of either ISFS or ARB facilities by private industry. This may require a cooperative effort on the part of affected utilities or the formation of private entities whose function is to construct and operate these facilities.

In Option A of Alternative 2 (designated Alternative 2A), new ISFS facilities are assumed to be built by private industry, as required. The accumulation of spent fuel in reactor basins is assumed to be limited to maintain capability for one annual discharge until full-scale operation of a disposition facility allows full-core reserve to be maintained in reactor basins. The disposition facility is assumed to be available on the same schedule as in Alternative 1 (the policy implemented alternative). For startup of the disposition facility in the year 1985, full-core reserve is attained by the year 1991 for Alternative 2A.
6-b (It is recognized that the disposition facility will probably not be available as early as the year 1985.) Spent fuel movements and inventories under Alternative 2A are identical to those in Alternative 1B-2 and are shown in Table III-4 for startup of the disposition facility in the year 1985 and in Table III-5 for 1995 startup of the facility. Facility requirements under Alternative 2A are the same as those determined for Alternative 1B-2.

In Option B of Alternative 2 (designated Alternative 2B), new interim storage basins are assumed to be built by private industry on reactor sites as needed. Transshipments are assumed to be minimized and used only as necessary to prevent reactor shutdown. Additionally, the accumulation of spent fuel in
C reactor discharge basins is assumed to be limited to maintain one annual discharge until private industry provides sufficient storage in the form of small "stand-alone" at-reactor basins (ARBs) to permit operation of reactor discharge basins with full-core reserve capability. The earliest these ARBs could be supplied is assumed to be the year 1983; and after that time, transshipments of spent fuel are no longer required. Startup of the disposition facility is assumed to be on the same schedule as Alternative 1 (the policy implemented case). Spent fuel movements and inventories under Alternative 2B are shown in
C Table III-16 for startup of the disposition facility in the year 1985 and in Table III-17 for startup in the year 1995. At-reactor basin requirements for disposition facility startup in the years 1985, 1990, 1995, or 2000 are given in Figure III-6. Forty-five new ARBs will be required if the disposition facility becomes available in the year 1985. If the disposition facility is

delayed 5, 10, or 15 years (1990, 1995, or 2000 startup, respectively), 82, 93, or 95 ARBs will be required, respectively, as shown in Table III-18. If the disposition facility is delayed 25 or 55 years, each site housing reactors built before the year 2000 would have ARBs to store overflow from the reactor discharge basins. (See discussion on delayed disposition startup beyond the year 2000 in Section C.1.1.1 and Appendix E.)

TABLE III-16

Spent Fuel Shipments - Decentralized Storage in At-Reactor Basins - Policy Not Implemented (Alternative 2B)
1985 Startup of Disposition Facility

	At-Reactor Basin			*Disposition Facility*			
	Fuel Shipments, MTU			*Fuel Shipments, MTU*			
Year	*Reactor to ARB*	*ARB to Disposition Facility*	*Inventory, MTU*	*Reactor to Disposition Facility*	*ARB to Disposition Facility*	*Inventory, MTU*	*Transshipment Between Reactor Basins, MTU*
1978	-	-	0	-	-	0	109
1979	-	-	0	-	-	0	86
1980	-	-	0	-	-	0	129
1981	-	-	0	-	-	0	154
1982	-	-	0	-	-	0	172
1983	1160	-	1160	-	-	0	-
1984	1518	-	2678	-	-	0	-
1985	1571	-	4249	100	-	100	-
1986	469	-	4718	1600	-	1700	-
1987	715	-	5433	1600	-	3300	-
1988	-	-	5433	3155	-	6455	-
1989	-	1408	4025	3368	1408	11231	-
1990	-	1292	2733	3760	1292	16283	-
1991	-	962	1771	4268	962	21513	-
1992	-	751	1020	4453	751	26717	-
1993	-	672	348	4776	672	32165	-
1994	-	348	-	5026	348	37539	-
1995	-	-	-	5481	-	43020	-
1996	-	-	-	5478	-	48498	-
1997	-	-	-	5505	-	54003	-
1998	-	-	-	5965	-	59968	-
1999	-	-	-	6018	-	65986	-
2000	-	-	-	6406	-	72392	-

C | TABLE III-17

Spent Fuel Shipments - Decentralized Storage in At-Reactor Basins - Policy Not Implemented (Alternative 2B)
1995 Startup of Disposition Facility

	At-Reactor Basins			*Disposition Facility*			
	Fuel Shipments, MTU			*Fuel Shipments, MTU*			
Year	*Reactor to ARB*	*ARB to Disposition Facility*	*Inventory, MTU*	*Reactor to Disposition Facility*	*ARB to Disposition Facility*	*Inventory, MTU*	*Transshipment Between Reactor Basins, MTU*
1978	-	-	-	-	-	-	109
1979	-	-	-	-	-	-	86
1980	-	-	-	-	-	-	129
1981	-	-	-	-	-	-	154
1982	-	-	-	-	-	-	172
1983	1160	-	1160	-	-	-	-
1984	1518	-	2678	-	-	-	-
1985	1671	-	4344	-	-	-	-
1986	2069	-	6418	-	-	-	-
1987	2315	-	8733	-	-	-	-
1988	3155	-	11888	-	-	-	-
1989	3368	-	15256	-	-	-	-
1990	3760	-	19016	-	-	-	-
1991	4268	-	23284	-	-	-	-
1992	4453	-	27737	-	-	-	-
1993	4776	-	32513	-	-	-	-
1994	5026	-	37539	-	-	-	-
1995	5381	-	42920	100	-	100	-
1996	3878	-	46798	1600	-	1700	-
1997	3905	-	50703	1600	-	3300	-
1998	1765	-	52468	4200	-	7500	-
1999	-	880	51588	6018	880	14398	-
2000	-	1000	50588	6406	1000	21804	-

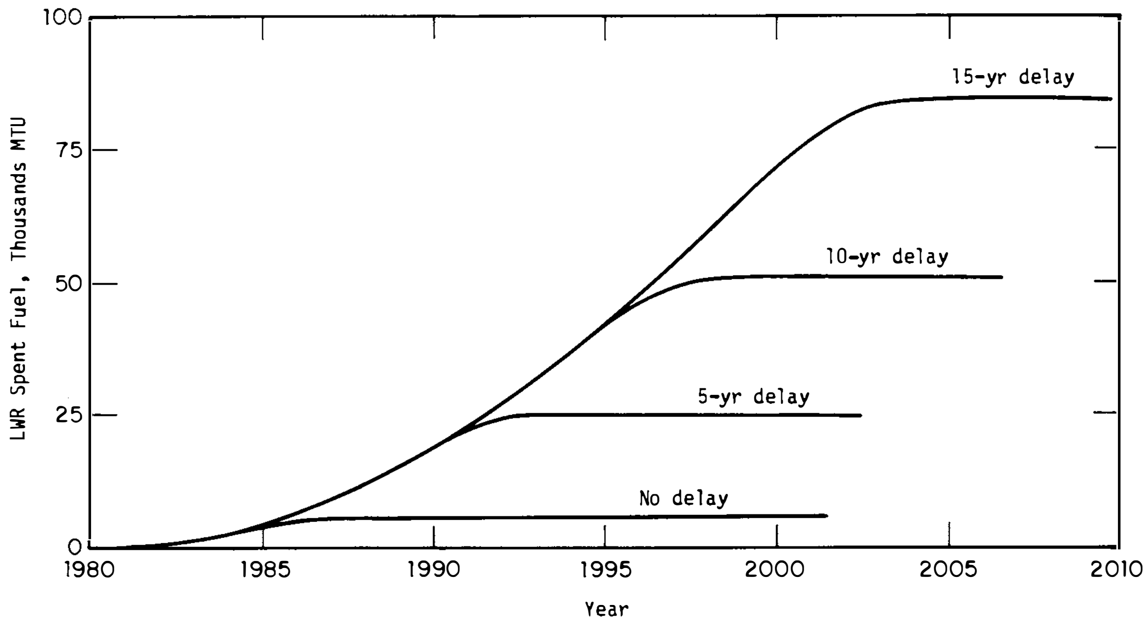

FIGURE III-6. Effects of Delays in Disposition on Capacity Required in At-Reactor Basin Storage

C | TABLE III-18

Requirements for At-Reactor Basins — Policy Not Implemented (Alternative 2B)

Disposition Facility Startup	*Total ARBs*	*Number by Basin Size Capacity, MTU*				
		500	*1000*	*1500*	*2000*	*2500*
1985	45	43	2			
1990	82	65	17			
1995	93	56	34	3		
2000	95	26	54	13	1	1

The Alternative 2B fuel shipment schedule (Table III-16) forecasts a total of about 650 MTU transshipments during the period 1978 to 1983 as necessary shipments between existing reactor basins to prevent reactor shutdown (no transshipments are forecast in the year 1983 when at-reactor basins become available). If these transshipments are not allowed, some
C reactors would have been or will be shut down due to the lack of spent fuel storage capacity. Such shutdowns are summarized in Table III-19.

C TABLE III-19

Reactor Shutdowns Expected if Transshipments Are Not Allowed in Period 1978 Through 1982

Year	*Number of Reactors Shut Down*[a]	*Annual Loss of Generating Capacity, MWe*[b]	*Cumulative Generating Power Loss, MWe-yr*[c]
C 1978	3(2470)	2470	2470
1979	1 (50)	2520	4990
1980	3(1510)	4030	9020
1981	1 (200)	4230	13,250
1982	1 (60)	4290	17,540

a. Numbers in parentheses are generating capacity (MWe) lost by shutdown of reactors in the year indicated.

b. Annual loss if all reactors remain shut down.

c. Cumulative power loss if all reactors remain shut down.

C.2.2 Evaluation of Environmental Impact of Alternative 2A

Use of natural resources, normal releases of radioactivity, population doses, health effects, and occupational exposures and accidents for Alternative 2A are the same as for Alternative 1B-2. These environmental effects are shown in Tables III-10, III-11, III-12, III-13, and VI-1.

C.2.3 Evaluation of Environmental Impact of Alternative 2B

C.2.3.1 Use of Natural Resources

Resource commitments for materials and energy under Alternative 2B are given in Table VI-1. The most significant increases in consumption if the disposition facility is delayed until the year 1995 are given below.

In comparison to the 1985 startup of the disposition facility,

- Coal consumption increases about 6-fold to 8 million tonnes.
- Electricity consumption increases about 7-fold to 1.4×10^3 MW-yr.
- Manpower use increases 80 million man-hours to 190 million man-hours.
- Chromium and nickel consumption increases because use of stainless steel increases about 4×10^4 tonnes to 6×10^4 tonnes; however, most of the stainless steel can be recycled if required.
- Steel consumption increases about 2-fold to 3×10^5 tonnes, primarily because of construction of additional ARB basins.

C.2.3.2 Radiological Effects of Normal Operations

Sources of Radiological Effects During Normal Operations — The radionuclides that are assumed to be released to the atmosphere under Alternative 2B (storage in at-reactor basins) are shown in
C | Table III-20. Releases are shown for 1985 startup of the disposition facility and for a startup in the year 1995 (ten-year delay). Releases from cask ventings and normal operations at ARBs are discussed more fully in the information provided in Appendices B, C, and D.

C | TABLE III-20

Radionuclides Released to the Atmosphere from Decentralized Storage Operations in At-Reactor Basins — Policy Not Implemented (Alternative 2B)

	Cumulative Release, curies					
	Disposition Facility Startup, 1985			*Disposition Facility Startup, 1995*		
Nuclide[a]	*Cask Venting*	*ARB Operations*	*Total*	*Cask Venting*	*ARB Operations*	*Total*
^{3}H	2.2×10^{0}	9.8×10^{1}	1.0×10^{2}	2.2×10^{1}	8.1×10^{2}	8.3×10^{2}
^{14}C	1.1×10^{-2}	5.4×10^{-1}	5.5×10^{-1}	1.0×10^{-1}	5.2×10^{0}	5.3×10^{0}
^{85}Kr	1.4×10^{3}	6.3×10^{4}	6.4×10^{4}	1.4×10^{4}	5.1×10^{5}	5.2×10^{5}
^{129}I	2.0×10^{-6}	1.0×10^{-3}	1.0×10^{-3}	1.9×10^{-5}	9.7×10^{-3}	9.7×10^{-3}
^{59}Fe	-	2.4×10^{-1}	2.4×10^{-1}	-	1.6×10^{0}	1.6×10^{0}
^{60}Co	-	3.0×10^{-1}	3.0×10^{-1}	-	2.0×10^{0}	2.0×10^{0}
^{90}Sr	7.7×10^{-6}	6.0×10^{-2}	6.0×10^{-2}	2.7×10^{-5}	9.0×10^{-1}	9.0×10^{-1}
^{134}Cs	6.8×10^{-6}	7.2×10^{-1}	7.2×10^{-1}	2.4×10^{-5}	4.8×10^{0}	4.8×10^{0}
^{137}Cs	1.1×10^{-5}	4.7×10^{0}	4.7×10^{0}	3.7×10^{-5}	3.1×10^{1}	3.1×10^{1}

a. Nuclides expected to contribute significantly to the dose from ARB facility operations. Radionuclides released during cask venting account for a small part of the total dose and are discussed more fully in Appendices B, C, and D.

Population Doses — The doses calculated for local, U.S., and world populations during the period of operation and the next 100 years are given in Table III-21. The doses result from transport of fuel, cask ventings, and normal operations at at-reactor basins. The whole body dose to the world population increases from 3500 man-rem to 21,800 man-rem if the disposition facility is delayed ten years. For perspective, this dose is a very small fraction of the exposure to the world population from natural radiation sources in the same period (about 2×10^{11} man-rem).

The maximum whole body dose commitment to an individual in the offsite population in any year is expected to be 0.5 mrem if the disposition facility begins operation in the year 1985 and is expected to increase to about 0.7 mrem if the facility is delayed ten years. For perspective, the maximum dose commitment to an individual from basin operations is small compared with the exposure from natural radiation sources that averages 100 mrem/yr in the entire world.

Population Health Effects — Health effects calculated from the world population dose for the period of operation and the next 100 years are shown in Table III-22. These effects were calculated as described in Section III C.1.2.2. The total number of health effects in the world population under these assumptions is two if the disposition facility begins operation in the year 1985 and increases to about 13 if the facility is delayed ten years.

Occupational Radiation Exposure — The occupational radiation dose to the work force under Alternative 2B was also calculated as described in Section III C.1.2.2. It is expected to be about 5600 man-rem if the disposition facility begins operation in the year 1985, as shown in Table III-23. If the disposition facility is delayed ten years (1995 startup), the occupational dose is expected to increase to 28,000 man-rem.

C | TABLE III-21

Population Dose Commitment for Decentralized Storage Operations in At-Reactor Basins - Policy Not Implemented (Alternative 2B)

	Population Dose, man-rem[a]							
	Disposition Facility Startup, 1985				Disposition Facility Startup, 1995			
Organ	*Local, 80-km radius*	*U.S., Less Local*	*World, Less U.S.*	*Total for Entire Period*	*Local, 80-km radius*	*U.S., Less Local*	*World, Less U.S.*	*Total for Entire Period*
Whole Body[b]								
Transportation - external gamma	14	210	-	220	21	240	-	260
Releases during cask venting	2	4	21 (12)	27 (18)	3	4	36 (20)	43 (27)
ARB - Normal operations	1800	1400	64 (36)	3300	11,500	9200	750 (410)	21,500 (21,100)
Total	1800	1600	85 (48)	3500	11,500	9400	790 (430)	21,800 (21,400)
Thyroid[c]								
Releases during cask venting	58	54	-	110	67	61	-	130
ARB - Normal operations	4	4	-	8	42	36	-	78
Total	62	59	-	120	109	97	-	210
Bone[c]								
Releases during cask venting	<1	<1	-	<1	<1	<1	-	<1
ARB - Normal operations	220	180	-	400	1,400	1100	-	2,500
Total	220	180	-	400	1,400	1100	-	2,500
Lung[c]								
Releases during cask venting	<1	<1	21	21	<1	<1	36	36
ARB - Normal operations	<1	<1	66	66	6	19	710	740
Total	<1	<1	87	87	6	19	750	780
Red Marrow[c]								
Releases during cask venting	<1	<1	19	19	<1	<1	32	32
ARB - Normal operations	<1	2	55	57	3	14	700	720
Total	<1	2	74	76	3	14	730	750

a. Continued effects of releases are included for a 100-year period after end of operations.

b. Gonad doses shown in parentheses when gonad doses differ from whole body doses.

c. Doses in addition to organ dose from whole body irradiation.

C TABLE III-22

Calculated Population Health Effects for Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)

Facility or Process	*Population Health Effects*[a] *Disposition Facility Startup* *1985*	*1995*
E Transportation	1.3×10^{-1}	1.6×10^{-1}
Cask Venting	2.3×10^{-2}	3.4×10^{-2}
ISFS Operations[b]	1.9×10^{0}	1.3×10^{1}
Total	2.1×10^{0}	1.3×10^{1}

a. Health effects calculated with EPA dose-effect factors for exposures during the period of operation and for the next 100 years.

b. Includes somatic effects from Table B-14 and genetic effects from Table B-16.

C TABLE III-23

Occupational Doses for Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)

Facility or Process	*Whole Body Dose, man-rem*[a] *Disposition Facility Startup* *1985*	*1995*
Transportation	590	720
ISFS	5000	27,000
Total	5600	28,000

a. For period of operation.

C.2.3.3 Occupational Accidents

7-j Occupational accidents (including construction accidents) under Alternative 2B are expected to result in about 23 deaths in the work force if the disposition facility begins operation in the year 1985; if the disposition facility is delayed ten years (1995 startup), the number of accidental deaths in the work force is expected to increase to about 42. Details on development of these values can be found in Appendix B. For perspective, the expected number of deaths from occupational accidents in this alternative can be compared with the 12,500 deaths in the year 1976 from occupational accidents in the U.S.

C.3 Radiation Effects from Abnormal Events

In this section, the releases of radioactive materials to the environment from postulated accidents at the ISFS or ARB facilities and during transport are assessed in terms of dose commitment and risk to a hypothetical individual receiving the
8-b maximum dose. No near-term biological effects are expected from doses from any of the postulated accidents.

8-a Population dose exposures for these accidents were not prepared in this generic EIS due to the uncertain results that would accrue from the assumptions in the following areas needed for a generic analysis:

- Demography around the site and along transportation routes and corridors
- Population emergency response variation at facility sites — suburban vs. rural responses
- Availability and proficiency of emergency response groups after a transportation accident as a function of the mode of transportation, route, and potentially affected population
- Weather patterns (prevailing wind speeds, directions, frequency of inversions) at the facility site or along transportation routes
- Topography of/and around the site or around a transportation accident
- Actual distance to the site boundaries from a facility accident or distance between a transportation accident and the potentially affected population
- Location of drinking water and food sources for the surrounding population — also consumption rates of the above.

8-a Since information in each of the above areas would be much better defined in a site-specific analysis, if the Policy is implemented, DOE will determine a maximum individual dose estimate and a population dose estimate for facility accident scenarios for each of the involved sites and the associated transportation routes and corridors.

C.3.1 Storage Basins

A wide range of accidents postulated for an ISFS or ARB facility has been analyzed. Those accidents which result in radioactive releases from the facility are classified either as operating incidents or severe accidents, depending upon the release potential and the frequency of occurrence. Releases from operating incidents are included in the normal radiological releases (Section III C.1 and III C.2). Severe accidents are discussed briefly in the following paragraphs and more fully in Appendix B.

Tornado and Earthquake — The basins will be designed to retain their watertight integrity for all credible accidents, including the design-basis tornadoes and earthquakes. These basins will be Category 1 seismic structures and, as such, designed to 1) resist rupture, which would cause excessive loss of water and 2) support and prevent all massive equipment, such as cranes, etc., from falling into the basins, thus causing damage to the spent fuel during the design-basis earthquake. The water shielding of the fuel will mitigate the effect of tornadic or other wind-driven missiles. Because of this protection, the basin roof is light industrial construction that could blow away in tornadic winds.

The postulated accident given detailed assessment in this section is a tornado with a translational velocity of 31 m/sec that is assumed to make a single pass across a storage basin. The blow-away roof fails, exposing the basin water. Passage of the tornado is assumed to disperse part of the basin water and
C associated radioactivity. The radwaste treatment systems, which are in a tornado-resistant Category 1 structure, are expected to be undamaged.

Criticality — A criticality incident (i.e., an accidental self-supporting nuclear chain reaction) in a storage basin is an unlikely event because equipment and processes are designed to prevent such incidents. Safe spacing is assured in storage basins by physically spacing the fuel assemblies in storage racks in a safe pattern even if a fuel assembly is dropped. Process systems and controls are designed to prevent assemblage of an unsafe array. To date, there have been no criticality accidents in spent fuel storage pools. Nevertheless, in this volume, a criticality excursion of 10^{18} fissions[13] is postulated in the storage basin. The excursion is assumed to occur as a result of fuel storage basket drop (personnel error). The criticality is assumed to occur at the bottom of a transfer aisle (connecting the fuel unloading pools to the storage basins) and involves four PWR assemblies (the maximum weight of uranium dioxide handled together in the facility). Several levels of control are assumed to be violated before critical geometry can be achieved. The cladding is assumed to rupture on all fuel elements, releasing the gap activity to the basin water. All volatiles formed during the excursion are assumed to be released to the basin water. The accident will be terminated by relocation of the fissile materials to a noncritical configuration by thermal and/or mechanical changes caused by the criticality. All the particulate material and 99% of the halogens are assumed to be retained by the basin water.

Maximum Dose to an Individual — The maximum dose commitment expected from radionuclides released during tornadoes and criticality events at storage basins is given in Table III-24 for each alternative. This is the maximum dose received by an individual at the site boundary at the time of the accident and is calculated by using meteorological dispersion conditions from Regulatory Guide 1.3.[14] For tornadic events, the dose is expected to increase with increased size of the storage facility because of the greater amount of pool water dispersed at the larger facilities. Loss of basin water during a tornado (or earthquake) will not be sufficient to reduce water shielding over fuel elements and cause exposures to an individual at the site boundary. The dose from criticality accidents is not expected to be affected by facility size.

Annual Risk to Maximum Offsite Individual — The annual risk to the maximum offsite individual from the postulated accidents is given in Table III-25 for each alternative. This risk is the product of the calculated consequence (expressed as dose commitment) and the probability of the event (expressed as events per year). The probability that a tornado or criticality accident will occur at a given site is about the same for each alternative. However, the annual risk to the maximum individual from tornadoes is expected to increase with increased facility size because the consequences are greater, whereas the risk from criticality events is about the same for each alternative.

C.3.2 Transportation

Irradiated fuel is transported in rugged casks specifically designed and tested to ensure retention of the contents during severe transportation accidents. If the cask is involved in moderate or severe accidents, cladding failure may occur, but the

C | TABLE III-24

Maximum Individual Dose from Release Associated with Extreme Abnormal Events, mrem/accident

Disposition Facility Startup →	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*		*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*
Event						
Storage Basin						
Tornado						
Body	1.9×10^{-3}	5.7×10^{-3}[a]	1.9×10^{-4}	1.9×10^{-3}	3.8×10^{-4}	3.8×10^{-4}
Bone	9.0×10^{-3}	2.7×10^{-2}[b]	9.0×10^{-4}	9.0×10^{-3}	1.8×10^{-3}	1.8×10^{-3}
Criticality						
Body	2.0×10^{1}	2.0×10^{1}	2.0×10^{1}	2.0×10^{1}	2.0×10^{1}	2.0×10^{1}
Bone	9.7×10^{-4}	9.7×10^{-4}	9.7×10^{-4}	9.7×10^{-4}	9.7×10^{-4}	9.7×10^{-4}
Thyroid	1.3×10^{0}	1.3×10^{0}	1.3×10^{0}	1.3×10^{0}	1.3×10^{0}	1.3×10^{0}
Transportation						
Body	4.0×10^{2}	4.0×10^{2}	4.0×10^{2}	4.0×10^{2}	4.0×10^{2}	4.0×10^{2}
Bone	1.7×10^{4}	1.7×10^{4}	1.7×10^{4}	1.7×10^{4}	1.7×10^{4}	1.7×10^{4}

a. 1.9×10^{-3} for Alternative 1B-1.

b. 9.0×10^{-3} for Alternative 1B-1.

C | TABLE III-25

Maximum Annual Dose Risk to an Individual from Extreme Abnormal Events, mrem/yr

	Disposition Facility Startup →	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*		*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)*	
		1985	*1995*	*1985*	*1995*	*1985*	*1995*
	Event						
	Storage Basin						
	Tornado						
E	Body	2×10^{-8}	6×10^{-8}[a]	2×10^{-9}	2×10^{-8}	4×10^{-9}	4×10^{-9}
	Bone	9×10^{-8}	3×10^{-7}[b]	9×10^{-9}	9×10^{-8}	2×10^{-8}	2×10^{-8}
	Criticality						
	Body	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}
	Bone	1×10^{-8}	1×10^{-8}	1×10^{-8}	1×10^{-8}	1×10^{-8}	1×10^{-8}
C	Thyroid	2×10^{-5}	2×10^{-5}	2×10^{-5}	2×10^{-5}	2×10^{-5}	2×10^{-5}
	Transportation						
	Body	8×10^{-3}	8×10^{-3}	8×10^{-3}	8×10^{-3}	8×10^{-3}	8×10^{-3}
	Bone	4×10^{-1}	4×10^{-1}	4×10^{-1}	4×10^{-1}	4×10^{-1}	4×10^{-1}

a. 2×10^{-8} for Alternative 1B-1.

b. 9×10^{-8} for Alternative 1B-1.

cask is expected to remain intact. Extreme accidents, which have a very low probability of occurring, may cause breaching of the
C cask containment. Unless the cask containing long-cooled spent fuel is breached, radionuclides released to the cask interior from fuel rods that suffer cladding failures will not be released to the environment until the cask is vented at the receiving facility. If the cask is breached, the release will occur at the accident site. The release of radionuclides, consequences of the release, and risk from transportation accidents of different severities are discussed in Appendix C.

8-b <u>Maximum Dose to an Individual</u> - Inhalation or ingestion of radionuclides released from accidents that breach a shipping cask would occur in a short time, but the radiation dose would be protracted over many years because some of the radionuclides would remain in the body. The maximum dose commitment to an
C individual downwind of an extreme accident involving long-cooled spent fuel that results in breaching of the cask is given in Table III-22.* The maximum dose commitment from this accident is expected to be about the same for each alternative because individual cask loadings are the same.

8-b The consequences of a transportation accident that breaches a spent fuel shipping cask are a function of the cooling time of the spent fuel and the effectiveness of emergency actions. If a rail cask with 0.5 yr fuel in its water-filled cavity is involved in an extreme transportation accident and no emergency action is taken to cool the exterior of that cask for several days, then the whole body dose to the maximum individual may be as great as 120 rems from inhaled radionuclides.[15] (See Appendix C of this volume for further discussion of this accident.) This discussion is included in this section to show the effects of cooling time on spent fuel accidents.

This short-cooled no-emergency-response accident scenario applies only to fuels which are cooled less than two years and are shipped in casks with water-filled cavities where no emergency action is taken to cool the exterior of the cask for several days. These consequences are not shown on Table III-22 nor included in the summary because this accident is not considered credible for the action involved under the Spent Fuel Storage Policy. It is incredible for the following reasons

- Federal regulation 10 CFR-73 (on physical protection of spent fuel during transport) is an interim final rule and requires escorts for spent fuel safeguard purposes. These escorts are also trained to mitigate consequence of accidents.

*Accident consequences determined for spent fuel cooled a minimum of four years. Most spent fuel handled under the Spent Fuel Storage Policy will be cooled longer than four years.

8-b • Emergency actions should be available before several days to cool the spent fuel casks.

Annual Risk to Maximum Individual - The annual risk to the maximum individual from the postulated transportation accident is given in Table III-23. As shown in the table, risk is essentially the same for each alternative.

REFERENCES FOR SECTION III

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2. A. B. Johnson. Behavior of Spent Nuclear Fuel in Water Pool Storage. USERDA Report BNWL-2256, Battelle Pacific Northwest Laboratories, Richland, WA (September 1977).

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4. Analytical Methodology and Facility and Environmental Description — Spent Fuel Policy. USDOE Report DOE-ET-0054, U.S. Department of Energy, Washington, DC (August 1978).

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7. The Effects on Populations of Exposures to Low Levels of Ionizing Radiation. BEIR Report, National Academy of Sciences and National Research Council, Washington, DC (November 1972).

8. Environmental Analysis of the Uranium Fuel Cycle. USEPA Report EPA-520/9-73-003B, U.S. Environmental Protection Agency, Washington, DC (1973).

9. Radiological Quality of the Environment in the United States, 1977. USEPA Report EPA-520/1-77-009, U.S. Environmental Protection Agency, Washington, DC (1977).

10. U.S. Code of Federal Regulations, Title 10, Part 20, (10 CFR 20), U.S. Government Printing Office, Washington, DC (1976).

11. Generic Environmental Statement on the Use of Plutonium in Mixed Oxide Fuel (GESMO). Report NUREG-0002, U.S. Nuclear Regulatory Commission, Washington, DC (1976).

12. "Facilities General Design Criteria." USERDA Manual. Appendix 6301, U.S. Energy Research and Development Administration, Washington, DC (1977).

13. Safety Evaluation Report — Barnwell Fuel Receiving and Storage Station. Report NUREG-0009, U.S. Nuclear Regulatory Commission, Washington, DC (1976).

14. U.S. Nuclear Regulatory Guide 1.3. U.S. Nuclear Regulatory Commission, Division of Materials and Fuel Cycle Licensing, Washington, DC (Revision June 1974).

15. Draft Environmental Impact Statement — Management of Commercially Generated Radioactive Waste. USDOE Report DOE/EIS-0046-D, U.S. Department of Energy, Washington, DC (April 1979).

IV. SAFEGUARDS

The transportation and storage activities described in this volume involve radioactive and fissionable material which can, under certain circumstances, be misused to create an unacceptable public risk. Examples of situations which might represent such circumstances and the resulting risk to the public are described in this section. Risk in the context of the Safeguards Section is the combination of the probability of a threatening act being attempted, the probability of the act being successful, and the probability that it presents a hazard to the public.

It is assumed that an ISFS or ARB facility will meet licensing requirements. Furthermore, the Presidential offer to submit U.S. facilities to IAEA safeguard inspections and the limited offer by the U.S. to consider storage of some spent fuel from other countries would result in the proposed basin storage facility coming under a US/IAEA agreement. A proposed formal agreement between the U.S. Government and IAEA for applying IAEA safeguards in the U.S. has been submitted to the U.S. Senate for its advice and consent for ratification as a treaty. The US/IAEA agreement would contain provisions which parallel agreements between IAEA and nonweapon states, the principal difference being the exclusion of national security activities. Implementation of such an agreement will require revision of NRC regulations concerning safeguard activities of licensees. NRC has proposed a new set of regulations ("Safeguards on Nuclear Material — Implementation of US/IAEA Agreement" — 10 CFR 75) and associated revisions to five existing sets of regulations.[1]

A. Threat Definition

Threats involving radioactive and fissionable materials fall into four categories: 1) theft or diversion of fissionable material with intent to construct an improvised nuclear device, 2) theft with intent to disperse the material as a radioactive contaminant, 3) sabotage with intent to disperse as a radioactive contaminant, and 4) theft with intent to blackmail municipalities or other domestic government groups by threatened subsequent sabotage or dispersal of radioactive material. For activities with domestic spent fuel described in this volume, sabotage at facilities and during transportation or theft for later malevolent purposes is unlikely, but the theft or diversion of spent fuel for ultimate construction of an improvised nuclear device appears much less credible.

Potential originators of the above threats can be further broken into 12 groups: individuals, ad hoc organizations, organized criminals, dissident employees, sociopathic groups, domestic separatists, domestic revolutionary groups, reactionary extremists, violent issue-oriented groups, domestic anarchists, foreign separatists, and foreign revolutionaries. A summary judgment of the threat capability and generalized objectives of each of these subnational groups are presented in Table IV-1.

A general evaluation by NRC of those groups described in Table IV-1 is that those groups that now have the means to mount a credible threat appear to lack the motive, while those groups that have the motive lack that means.[2] Individuals, dissident employees, extremists, and other domestic groups may select nuclear targets, but none has yet demonstrated the ability to do more than harass or disrupt operations. Sophisticated criminal groups, foreign separatists, and foreign revolutionaries have all shown, upon occasion, the skill and resources that might be required to overcome a nuclear facility or shipment. However, these groups seem to lack the incentive to mount a credible threat. They are unlikely to attack the U.S. nuclear facilities (an extremely provocative act) unless their relationships with the U.S. deteriorate.

The theft and subsequent chemical separation and recovery of fissionable material for the manufacture of clandestine improvised nuclear devices from the activities described in this volume would require 1) overcoming personnel and systems especially designed to protect the material, 2) removing the highly radioactive spent fuel elements from their storage or transportation environment, 3) transporting the fuel elements to a clandestine reprocessing plant, 4) processing the fuel elements in a shielded and remotely controlled facility to separate plutonium from fission products and uranium, 5) converting the plutonium to a usable form, and 6) manufacturing a nuclear weapon.

Step 1 of this sequence involves an obvious criminal act that would initiate retaliatory efforts to prevent completion of subsequent steps. Steps 2 through 6 each involve both relatively complex technical processes and the facilities necessary to shield the radiation levels of the spent fuel to a manageable level. The complex technical processes and the heavily shielded process facilities require capital and skilled technical personnel. Based upon consideration of these difficulties and the likely resources, capabilities, and motivation of a subnational threat group, it is concluded that the theft and subsequent recovery of fissionable material from spent fuel in the operations discussed in this volume are not a credible occurrence.

TABLE IV-1[a]

Characterization of Threat Groups

Group	*Objective*	*Target*	*Skill Level*	*Motivation Level*	*Equipment Level*	*Risk Acceptance Level*
Individual (outsider)	Protest, revenge, financial gain	Lightly protected facilities or people	Low	Low to average	Low	Low
Ad-hoc group	Normally financial gain	Typically large robberies or kidnapping	Low to average	Low	Low to average	Low
Criminal group	Financial	Anything marketable	Average to high	Average	Average	Average
Dissident employee (insider)	Revenge	Institutional	Generally low	Low to average	Low	Low
Sociopathic group	Thrill of act	Symbols of authority	Low	Average to high	Low	High
Domestic separatists	Form separate nations	Publicity oriented	Low	High	Low	Average
Domestic revolutionary groups	Overthrow government	Symbols of government or financial power	Average	High	Average	Average
Reactionary extremists	Protect the "system"	Leftist activities	Average	Low	High	Low
Issue-oriented groups	Protest	Some social change	Low	Low	Low	Low
Domestic anarchists	Eliminate government	Personalities	Low to Average	Average	Low	High
Foreign separatists	Recognition of movement	Groups with identifiable characteristics	Average	High	Average to high	Average
Foreign revolutionaries	Political changes	Local political institutions	Average	High	Average to high	Average

a. Adapted from Reference 2.

The skill, motivation, equipment, and risk acceptance required for dispersal and sabotage attempts are, however, more modest. These categories require a modest range of technical expertise — usually, relating only to explosives and firearms. Sabotage of a storage basin by disrupting the fuel spacing in a way that results in a supercritical array would require some background knowledge of neutronics but little specialized training or equipment. Thus, destruction of a cask carrier, rupture of a cask, sabotage of a storage basin or of the surface operations at the geologic repositories are all within the capability of several of the groups listed in Table IV-1. The following sections discuss specific requirements for these incidents and describe the environmental effects that might result.

B. Incident Analysis

10-a B.1 Transportation Sabotage

Spent fuel is shipped by rail or truck, in massive shipping casks which have been designed and demonstrated to withstand severe accidents and, thus, would be resistant to release of contents as a result of all but the most severe attacks. In a 1977 document (NUREG-0170),[3] which dealt with generic transportation risks, the NRC concluded that:

> Shipments of radioactive materials not now covered by NRC physical protection requirements, such as spent fuel and large source nonfissile radioisotopes, do not constitute a threat to the public health and safety either because of their limited potential for misuse (due in part to the hazardous radiation levels which preclude direct handling) or because of the protection afforded by safety considerations, e.g., shipping containers.

However, possible results of severe attacks were reconsidered in a May 1978 NRC working draft of a Generic Environmental Assessment on transportation of radioactive material in an urban area (Urban Study).[4] This draft investigation reflected detailed consideration of the special characteristics of urban areas as they might be impacted by transport of radioactive material. The report concluded that shipping casks could be penetrated by using quantities of explosives obtainable by terrorists and by using specialized modes of an attack. This analysis was based upon assumed release models and damage mechanisms which would provide the most severe results. Those assumptions are the subject of research programs funded by both DOE and NRC which will be completed in 1981.

10-a The Urban Study draft has become the technical basis for a modification of physical protection regulations (10 CFR 73[5,6]) for NRC. The revised regulations require NRC approval of shipping routes and specify escort surveillance and emergency response training. These regulations are established and enforced by NRC with the intent of assuring that adequate safety and environmental protection are provided to prevent or mitigate sabotage conditions. Commercial shipments of spent fuel to DOE storage facilities will be in licensed casks and will meet NRC regulations.

These rules, together with the observations that:

- Normal routing of spent fuel shipments generally avoids areas capable of producing "worst case" incidents for practical reasons unrelated to safeguards, and

- "Worst case" incidents require several attackers, technical ability concerning explosives, solutions to the logistical problems of obtaining, securing, and transporting necessary quantities of explosives; knowledge of spent fuel cask construction; optimal placement of the cask to cause the incident; and the absence of adequate law enforcement and citizen awareness prior to the possible sabotage event,

means that the risk to the public associated with these sabotage acts is low.

B.2 Storage Basin Sabotage

The fuel storage basin complex will be enclosed within a building constructed to meet the safeguard standards outlined in 10 CFR 73.[5] Protection against unauthorized intrusion will be provided by armed guards and an intruder detection system. Procedures will be established to augment the onsite force by local law enforcement support upon request. Other protection systems include alternative communication and power systems, high intensity lighting, and roving guard patrols.

Penetration of these systems by a casual or spontaneous attempt is very unlikely. The systems may, however, be penetrated by a thoroughly planned and well-armed attack group. At the first signs of an attack, the control room operation would alert local law enforcement agencies and help would start arriving within 15 minutes. Although the following analyses take no credit for the inhibiting effect these forces would have, it should be noted that none of the credible and effective modes of sabotage can be completed in less than 15 minutes and, hence, some sort of an engagement would take place.

The number of specific sabotage acts that may be attempted against the fuel storage basin is large. Several sabotage scenarios that might be typical of those associated with storage basins were analyzed. These are

- Damage to basin causing loss of water shielding and cooling
- Explosion within basin causing rupture of fuel and ejection of spent fuel debris to the environs
- Explosion adjacent to a fuel assembly suspended in air and ejection of debris to the environs
- Explosion producing nuclear criticality.

Analyses of the sabotage scenarios identified above show that an individual located on the plant boundary would receive a dose of less than three rem, which would not endanger his or her health.

C. Conclusion

Since spent fuel contains a large inventory of fission products, it is relatively unattractive and inaccessible to potential subnational misuse. Because of the difficulty of obtaining spent fuel and the radiation risk to those who handle it in makeshift equipment, the probability of a successful attempt to cause a dispersal or a criticality incident is very low. In addition, the level of consequences that could occur from the most credible sabotage scenarios is low and does not exceed the consequences of a similar sabotage incident not involving nuclear materials.

Property damage resulting from sabotage incidents would consist mostly of localized contamination, which would limit access until cleanup operations could be completed. It is concluded that storage of spent fuel in ISFS or ARB facilities and the associated transportation of spent fuel does not impose an unacceptable risk to the public.

D. Alternative of Policy Not Implemented

The alternative of not implementing the policy does not involve safeguards considerations that differ significantly from those discussed previously in this section. This alternative primarily involves a variation in the location of spent fuel storage and the timing of shipments of the spent fuel from the reactors, which are not expected to produce a significant change in the safeguards conclusions described above.

REFERENCES FOR SECTION IV

1. "Safeguards on Nuclear Material; Implementation of US/IAEA Agreement." Federal Register. Vol. 44, No. 138, U.S. Nuclear Regulatory Commission, Washington, DC (July 17, 1979).

2. N. R. Wagner. A Survey of Threat Studies Related to the Nuclear Power Industry. Report SAND-77-8254 (or NRC-13) Sandia Laboratories, Albuquerque, NM (August 1977).

3. Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes. Vol. 1, NUREG-0170, Docket No. PR-71, 73 (40 FR 23768), U.S. Nuclear Regulatory Commission, Washington, DC (December 1977).

4. A. R. DuCharme, Jr., et al. Transport of Radionuclides in Urban Areas: A Working Draft Assessment. Report SAND-77-1927, Sandia Laboratories, Albuquerque, NM (May 1978).

5. U.S. Code of Federal Regulations, Title 10, Part 73 (10 CFR 73). U.S. Government Printing Office, Washington, DC (1977).

6. "Physical Protection of Irradiated Reactor Fuels in Transit, 10 CFR 73 Revision." Federal Register. Vol. 44, No. 117, U.S. Nuclear Regulatory Commission, Washington, DC (June 15, 1979).

V. UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

A. Radiological

Calculated health effects resulting from released radioactivity in the event of policy implementation or no policy implementation are discussed in Section III and summarized in Table V-1. The radiation doses to the general population in either case are very small percentages of the doses from natural background; workers exposed to job-related radiation receive an average dose of three to four times natural background.

Radiological health effects for activities after shipment of spent fuel from reactors through unloading of casks at the site of final disposition are included in Table V-1. The number of potential health effects for a 1995 disposition date is five to seven times that for a 1985 disposition date; this increase is due primarily to the longer period of operation of the interim storage facilities and at-reactor-basin (ARB) facilities and a larger amount of spent fuel in storage. Worldwide population health effects are generally higher than occupational health effects except for the ARB Alternative (2B).

B. Potential Accidents

The potential adverse effects from radiological releases after possible accidents are well within the limits given in 10 CFR 100[1] and ERDA Manual, Appendix 6301[2] for DOE assessment of the adequacy of safety systems and exclusion boundaries against potential accidents. Details of the accidents considered are given in Section III and Appendices B and C of this volume. Transportation of spent fuel would be the principal cause of fatalities from nonradiological accidents except for Alternative 2B. Transportation deaths are between 9 and 11 for all alternatives. In Alternative 2B, fatalities to the construction workers at ARBs are 12 for disposition facility startup in the year 1985 and increase to 26 if the startup of the disposition facility is delayed until the year 1995. These higher construction deaths are due to the large number of small facilities constructed in that option.

C. Other

Land use for basin facilities is an unavoidable effect, but it is minor whether the policy is implemented or not implemented as shown in Table V-2. There would be no permanent commitment of land resources because the land can be returned to unrestricted use after decommissioning of the facilities.

TABLE V-1

Radiological Health Effects[a,b]

Disposition Facility Startup →	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*		*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage In At-Reactor Basins (Alternative 2B)*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*
Population	1	10	1	6	2	13
Work Force	1	4[c]	1	3	4	19
Total	2	14[c]	2	9	6	32

a. Total cancers and serious genetic effects are the sum of effects from whole body and individual organ dose commitment (based upon EPA dose-effect factors given in Appendix B).

b. Worldwide health effects through the period of operation plus 100 years thereafter.

c. For Alternative 1B-1, the number of health effects to the work force is 6, and the total health effects become 16.

TABLE V-2

Land Use Requirements for Storage Basin Facilities[a]

	Land Use, acres
Centralized Storage (Alternative 1A) — Policy Implemented	
Disposition Facility Startup, 1985	1000
Disposition Facility Startup, 1995	3000
Decentralized Storage with Full Core Reserve (1B-1) — Policy Implemented	
Disposition Facility Startup, 1985	1000
Disposition Facility Startup, 1995	9000
Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)	
Disposition Facility Startup, 1985	1000
Disposition Facility Startup, 1995	4000
Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)	
Disposition Facility Startup, 1985	0[b]
Disposition Facility Startup, 1995	0[b]

6-g *a.* Low-level waste from these operations is assumed to be buried and will result in land consumption of 0.1 to 14 acres. The lower case is Alternative 1B-1 or 2A with disposition facility startup in the year 1985. The largest quantity of land consumed results from Alternative 1B-1 with the disposition facility startup in the year 1995.

b. No additional land required for at-reactor basins since they are built on existing reactor sites.

Other unavoidable adverse environmental effects are water and power requirements and chemical discharges. These are discussed in Section VI and are not large in terms of available resources or environmental impact.

REFERENCES FOR SECTION V

1. U.S. Code of Federal Regulations, Title 10, Part 100, (10 CFR 100), U.S. Government Printing Office, Washington, DC (1975).

2. "Facilities General Design Criteria." USERDA Manual, Appendix 6301, U.S. Energy Research and Development Administration, Washington, DC (1974).

VI. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Resources that are committed in an irreversible and irretrievable manner by implementation of the policy consist of:

- Manpower for construction, operation and decommissioning of storage facilities, and transportation equipment affected by this policy, and

- Materials such as fuels and chemicals consumed, and construction materials that are not recyclable.

The estimate of principal resource commitments is shown in Table VI-1 for the alternatives considered for implementing the policy and for not implementing the policy.

No land areas are permanently committed by implementation of policy because decommissioning of the required interim storage facilities restores site areas to prefacility conditions. Disposition of spent fuel is not affected by this policy, and is therefore not included in this volume. Disposition of low-level radioactive wastes associated with interim storage facility operation and decontamination-decommissioning operations does not result in permanent land commitment since these wastes are assumed to contain less than 10 nCi transuranic isotopes per gram of wastes (see Appendix B). The effects of the startup date of the disposition facilities on resource requirements for the interim storage facilities and transportation are given in Table VI-1.

Some construction materials (denoted in Table VI-1) are expected to be recyclable. After decontamination of interim storage facilities and transportation casks, large portions of certain construction materials could be recoverable and recyclable if desired. For example, nearly all of the stainless steel in storage facilities (4000 tonnes for pool liners and storage baskets in the ISFS facility with 6000-MTU capacity) could be recycled.

TABLE VI-1

Resource Commitments for Interim Storage and Transportation

Disposition Facility Startup →	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1)[a] — Policy Implemented*				*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*				*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*			
	1985	*1990*	*1995*	*2000*	*1985*	*1990*	*1995*	*2000*	*1985*	*1990*	*1995*	*2000*
Resource												
Water, m^3	$5.3x10^6$	$3.4x10^7$	$7.2x10^7$	$1.0x10^8$	$9.3x10^5$	$1.7x10^7$	$3.4x10^7$	$5.7x10^7$	$1.8x10^7$	$4.2x10^7$	$1.0x10^8$	$1.6x10^8$
Materials												
Concrete, m^3	$2.3x10^4$	$6.8x10^4$	$1.2x10^5$	$2.1x10^5$	$6.7x10^3$	$3.3x10^4$	$7.1x10^4$	$1.6x10^5$	$3.0x10^5$	$5.6x10^5$	$6.5x10^5$	$6.9x10^5$
Steel, tonne	$2.1x10^4$	$5.9x10^4$	$1.1x10^5$	$1.8x10^5$	$6.1x10^3$	$2.8x10^4$	$5.8x10^4$	$1.2x10^5$	$1.5x10^5$	$2.8x10^5$	$3.4x10^5$	$3.8x10^5$
Copper,[a] tonne	$3.2x10^1$	$9.2x10^1$	$1.5x10^2$	$2.9x10^2$	$9.5x10^0$	$4.4x10^1$	$9.7x10^1$	$2.2x10^2$	$4.3x10^2$	$7.8x10^2$	$8.9x10^2$	$9.4x10^2$
Zinc,[a] tonne	$5.4x10^1$	$1.5x10^2$	$2.5x10^2$	$4.8x10^2$	$1.6x10^1$	$7.3x10^1$	$1.6x10^2$	$3.6x10^2$	$7.2x10^2$	$1.3x10^3$	$1.5x10^3$	$1.6x10^3$
Lumber, m^3	$1.3x10^3$	$3.8x10^3$	$6.1x10^3$	$1.2x10^4$	$3.9x10^2$	$1.8x10^3$	$4.0x10^3$	$8.9x10^3$	$1.8x10^4$	$3.2x10^4$	$3.7x10^4$	$3.8x10^4$
Lead,[a] tonne	$8.6x10^3$	$1.7x10^4$	$1.1x10^4$	$1.1x10^4$	$8.8x10^3$	$9.6x10^3$	$9.6x10^3$	$9.7x10^3$	$8.8x10^3$	$1.2x10^4$	$1.2x10^4$	$1.2x10^4$
Depleted Uranium,[a] tonne	$4.9x10^2$	$6.9x10^2$	$6.9x10^2$	$6.9x10^2$	$4.9x10^2$	$5.5x10^2$	$5.5x10^2$	$5.5x10^2$	$4.9x10^2$	$6.5x10^2$	$6.5x10^2$	$6.5x10^2$
Chromium in Stainless Steel,[b] tonne	$1.3x10^3$	$3.8x10^3$	$5.4x10^3$	$1.2x10^4$	$6.0x10^2$	$1.9x10^3$	$3.7x10^3$	$7.7x10^3$	$3.7x10^3$	$7.7x10^3$	$1.0x10^4$	$1.4x10^4$
Nickel in Stainless Steel,[b] tonne	$5.8x10^2$	$1.7x10^3$	$2.4x10^3$	$5.2x10^3$	$2.6x10^2$	$8.4x10^2$	$1.7x10^3$	$3.4x10^3$	$1.6x10^3$	$3.4x10^3$	$4.5x10^3$	$6.3x10^3$
Energy												
Propane, m^3	$5.9x10^2$	$1.7x10^3$	$2.7x10^3$	$5.2x10^3$	$1.7x10^2$	$8.0x10^2$	$1.8x10^3$	$4.0x10^3$	$7.7x10^3$	$1.4x10^4$	$1.6x10^4$	$1.7x10^4$
Diesel Fuel, m^3	$1.7x10^5$	$1.9x10^5$	$2.2x10^5$	$2.7x10^5$	$1.7x10^5$	$1.7x10^5$	$2.0x10^5$	$2.4x10^5$	$3.1x10^5$	$4.3x10^5$	$4.8x10^5$	$5.0x10^5$
Gasoline, m^3	$1.0x10^4$	$2.9x10^4$	$4.7x10^4$	$8.9x10^4$	$3.0x10^3$	$1.4x10^4$	$3.0x10^4$	$6.8x10^4$	$1.4x10^5$	$2.5x10^5$	$2.8x10^5$	$3.0x10^5$
Electricity, MW-yr	$6.5x10^1$	$5.0x10^2$	$1.0x10^3$	$1.5x10^3$	$8.2x10^0$	$2.3x10^2$	$5.0x10^2$	$8.3x10^2$	$1.8x10^2$	$5.6x10^2$	$1.4x10^3$	$2.2x10^3$
Coal,[c] tonne	$4.0x10^5$	$3.0x10^6$	$6.2x10^6$	$9.0x10^6$	$5.4x10^4$	$1.4x10^6$	$3.0x10^6$	$5.0x10^6$	$1.2x10^6$	$3.4x10^6$	$7.6x10^6$	$1.3x10^7$
Manpower, man-hours	$4.5x10^7$	$6.7x10^7$	$8.5x10^7$	$1.3x10^8$	$3.9x10^7$	$5.3x10^7$	$7.6x10^7$	$1.1x10^7$	$1.1x10^8$	$1.7x10^8$	$1.9x10^8$	$2.0x10^8$

a. The resource commitments for Alternative 1B-1 are similar to those shown for Alternative 1A but not exactly the same. The differences are small.
b. A large portion of these construction materials could be recovered during decommissioning of facilities and transportation casks if desirable.
c. Total cost for generation of process steam for building heat and generation of the electrical energy. In this volume, both process steam and electrical energy are assumed to be produced by coal-fired boilers.

VII. LOCAL SHORT-TERM USES OF ENVIRONMENT AS RELATED TO LONG-TERM PRODUCTIVITY

This section compares the short-term and long-term effects on the environment if the new Spent Fuel Storage Policy is implemented or not implemented. Short-term effects are considered to be those that occur during the period of construction and operation of facilities to provide storage for spent fuel. Long-term effects are those that extend past this period and into the indefinite future. Short-term effects are generally in terms of tradeoffs in land use and radiological impact on the environment. Long-term effects have to do with conservation of resources and diversity of land uses.

Both implementation and nonimplementation of the proposed spent fuel policy will require some use of resources and both will affect the environment. However, the differences are small and will not foreclose future options except to the extent that the resources are consumed. This consumption is a very small part of available resources.

This statement assumes that the continued growth of the LWR industry will be unaffected by implementation of the storage policy. If government-owned or -leased interim storage facilities are not constructed and operated, then private facilities could be expected to provide the required storage. However, it is recognized that in some cases this may not be practicable due to technical, institutional or regulatory reasons. These private facilities are expected to be smaller and more diverse than a centralized storage facility. In addition, if decentralized storage with capacity to maintain one scheduled annual discharge is assumed (as in Alternative 1B-2 of the Policy Implementation or Alternative 2A, Policy Not Implemented), less spent fuel will be stored in the ISFS basin facilities and more stored in reactor discharge basins. This increased fuel storage in reactor discharge basins will reduce flexibility in reactor operations and may lead to forced shutdowns due to lack of emergency storage space.

For Alternative 2B, storage in at-reactor basins (ARB), no ISFS facilities will be constructed; and all fuel not stored in reactor discharge basins will be stored in new basins constructed at the sites of commercial power reactors. In this alternative ARBs are assumed to have sufficient capacity to maintain full-core reserve and preclude forced reactor shutdown due to lack of emergency storage space.

Short-term Effects - Short-term uses of the environment include construction of ISFS and at-reactor storage facilities and supporting services such as roads, railroads, and transmission lines and operation of these facilities. These are regarded as slight changes having essentially no long-term impact. Construction and operation of the storage facilities under NRC licensing and according to EPA standards will protect the short-term use of the environment.

Long-term Effects - Some use of resources will be required for both implementation and nonimplementation of the proposed Spent Fuel Storage Policy. However, the differences between implementation and nonimplementation are small. The use of natural resources is small, does not vary greatly between alternatives, and is further discussed in Section VIII. Land use commitment is not permanent; all land will be available for other uses when restored after decommissioning of ISFS basin facilities or at-reactor storage facility portion of the reactor sites.

VIII. ENVIRONMENTAL TRADEOFF ANALYSIS

A. Introduction

This section addresses the environmental tradeoff between implementing or not implementing the proposed policy of providing interim storage for spent fuel from U.S. power reactors before final disposal of the fuel. Two alternatives have been identified, i.e., either the U.S. Government is assumed to implement the Spent Fuel Storage Policy, or the policy is assumed not to be implemented (the government does not take title to the spent fuel). A variation of the Policy Not Implemented alternative allows for encouragement by the Federal Government of at-reactor basin storage. Each alternative has several options to cover the possible range of fuel management under the new policy if it is implemented or not implemented. In both alternatives, the activities are similar for a given repository startup date, and environmental impacts vary with the amount of fuel received, the number of ISFS facilities required, the storage time, and to a lesser degree to the amount of spent fuel transported. The major difference between alternatives is the extent of U.S. Government involvement in providing facilities and management for the stored fuel.

Although environmental impacts of all alternatives are small, differences do exist. Centralized government ISFS facilities may have more transportation impact than private ARBs. However, ARBs result in greater radiological impact due to the increased number of facilities and larger work force. Decentralized ISFS facilities would have the same impacts regardless of whether or not the government provides them; however, institutional and regulatory problems are believed to be greater for private facilities.

When the draft version of this EIS[1] was prepared in the latter part of the year 1977 and early 1978, a national objective was to open the first geologic repository in 1985. Environmental effects from interim storage of spent reactor fuels were determined for disposition facility operation beginning in 1985 or 1995, and ISFS facility effects were determined through the year 2000 to ensure that the range of actions was covered by the EIS. The alternatives analyzed were Alternative 1 — Policy Implemented and Alternative 2 — Policy Not Implemented. Between the time the draft document and this final EIS was complete, DOE recognized that the first repository might not be in operation until the years 1997 to 2006. To demonstrate the effects of delayed repository opening beyond the year 1995, an appendix was prepared for this volume (Appendix E) to show the environmental effects with the first repository startup in the year 2010.

The analyses used to show the environmental effect comparison of disposition facility startup in the year 2010 were selected to parallel Alternatives 1 and 2 in the draft EIS. Although not true decision alternatives, these analyses have been labeled Alternative 3 — Policy Implemented and Alternative 4 — Policy Not

C Implemented. These alternative numbers were selected to differentiate between the alternatives which consider earlier startup dates for the disposition facility (Alternatives 1 and 2). Alternatives 3 and 4 (disposition facility startup in the year 2010) use an updated forecast of fuel flow and interim storage requirements than Alternatives 1 and 2, so Alternatives 1 and 2 cannot be directly compared to Alternatives 3 and 4. The comparison of environmental effects to be used in the decision to implement or not to implement the policy should be based on comparison of alternatives for the same disposition facility startup date.

In Alternatives 1 and 2, two major options were considered in which the reactor discharge basins were operated at full-core reserve and also at discharge capability (as described in Section II-D of this report). The full-core reserve option requires construction and operation of a larger number of storage basins (ISFS or ARB) than is required for discharge capacity. This extra capacity requirement is a result of less spent fuel stored in the reactor discharge basins. The impacts of this extra storage must be balanced against the reduced flexibility in reactor operation that would be encountered while operating reactor basins at less than full-core reserve and the possibility of forced shutdown* which could lead to the use of higher cost supplemental
C power or reduction of electrical power generation. Alternatives 3 and 4 only consider maintenance of full-core reserve storage capacity in reactor discharge basins.

Economic considerations associated with implementing the Spent Fuel Storage Policy are covered in Volume 4 of this EIS on the fee to be charged for storage and disposal of spent power reactor fuel.

Based upon the President's statement of October 18, 1977, the Federal Government is proposing to accept and take title[2] to spent nuclear fuel from utilities on payment to the government of a storage fee. The new policy is a relevant extension of the government's decision to defer indefinitely all civilian reprocessing of spent fuel in the United States. President Carter also asked other countries to join the U.S. in deferring use of reprocessing technology in order to evaluate alternative fuel cycles and processes which may reduce the risk of nuclear proliferation. Pending this evaluation, utilities are faced with the prospect of storing fuel discharged from reactors for an indefinite period with no approved plan for its ultimate disposition. This produces an increasing uncertainty in the economic calculations of the utilities, making advanced planning difficult.

* To date, power reactors have required full-core discharge approximately fifty times. Fortunately, full-core storage capability was available. If it had not been, arrangements to transfer fuel to another storage basin would probably require several months, and possibly over a year to accomplish. During this period, the reactor would be shut down.

The activities involved in implementing or not implementing the policy are similar but the environmental impacts vary with the amount of spent fuel received by the government for interim storage, the number of facilities required for interim storage, the storage time, and, to a lesser degree, to the differences in spent fuel transportation. The differences between comparable alternatives of implementing or not implementing the policy are small. Factors considered in the analysis of Alternatives 1 and 2 include

- Environmental effects
- Effects of delay in or reduction of transshipments
- Effects of changes in reracking in existing reactor discharge basins
- Effects of use of ISFS facilities compared with ARB facilities
- Institutional factors affecting centralized and decentralized ISFS facilities
- Institutional factors affecting ISFS or ARB facilities

Environmental effects of all alternatives are discussed in Section VIII-B. Other effects are discussed in the following paragraphs.

The effects of delay in or reduction of planned transshipping in Alternatives 1 and 2 depend upon the amount of excess space in reactor discharge basins at the time. Both delays or reductions require storage of additional spent fuel in reactor discharge basins, until additional basin space can be secured (bought, built, or leased) in ARBs or ISFSs. Thus, if a reactor discharge basin is being operated with full-core reserve capacity, the effects will be much less significant than if they are operating at discharge capacity. The transshipment schedule developed for Alternatives 1 and 2 was based upon 1978 utilities' projection of the need for spent fuel storage after considering their own plans to expand reactor discharge basin storage by reracking or by expansion. Alternatives 3 and 4, developed around DOE's current "Base Planning Case," do not consider transshipment of spent fuel. DOE does not include transshipment in their "Base Planning Case," but believes transshipment should serve as a backup to meet short-term and emergency needs and should not be a planning base for reactors.[3]

If reracking and/or expansion of existing reactor discharge basins is delayed by institutional constraints imposed by regulatory bodies, these delays would require building more ISFS or ARB facilities. If utilities conclude that increased storage density (described in Section II-D) is desirable, then the amount of required storage capacity in ISFS or ARB facilities would be reduced.

Use of ISFS facilities (compared to ARB facilities) would result in some additional land use in the U.S. and a small increase in shipment of spent fuel but less consumption of other resources. The land used to site the ISFS facilities is an additional commitment of land by the nuclear industry. ARB facilities are located on reactor sites and do not require this additional land. Alternatives that include use of ARB facilities reduce the amount of shipment required when compared with alternatives that use ISFS facilities due to the close proximity of the ARB facilities to the reactor discharge basin. The difference between planned shipments and minimum shipment results in a decrease of 4% of the total transportation of spent fuel. Use of ARB facilities, however, requires additional use of other resources to construct the larger number of ARB facilities at reactor sites than would be required to construct ISFS facilities.

Institutional effects of centralized ISFS would be less severe than that of decentralized ISFS basins due simply to the number of facilities required. Location of appropriate sites of the fewer centralized ISFS facilities would be simpler and less time consuming than the larger number of decentralized ISFS facilities. Some states have expressed their intent to preclude siting of spent fuel basins within their boundaries. On the other hand, selection of the centralized storage option carries with it the risk of public concern that this facility will store spent fuel from the entire nation and, with this, provide an undue risk to a few people who did not reap the benefit of the power generated by the nuclear fuel.

Siting of ARB facilities should be less involved than that of ISFS facilities since they will be located on existing reactor sites.

B. Summary of Environmental Effects

This section addresses the environmental tradeoff between implementing or not implementing the proposed policy. The activities involved in implementing or not implementing the policy are similar but the environmental impacts vary with the amount of spent fuel received by the government for interim storage, the number of facilities required for interim storage, the storage time, and, to a lesser degree, to the differences in spent fuel transportation. Alternatives 3 and 4 (initial repository startup in the year 2010) use a more recent forecast of fuel flow and interim storage requirements than Alternatives 1 and 2. The differences between comparable alternatives of implementing or not implementing the policy are small. The comparison of environmental effects to be used in the decision to implement or not to implement the policy should be based on comparison of alternatives for the same disposition facility startup date.

Table VIII-1 summarizes the environmental effects believed C to be more significant for Alternatives 1 and 2 for disposition beginning in the years 1985 and 1995. As shown in the table, the use of natural resources (materials and energy) are small and do not vary greatly between alternatives. Commitments of construction materials, coal, electricity, and manpower are slightly greater in the ARB storage option than in the option with centralized or decentralized ISFS storage primarily because of the construction and operation of a larger number of storage basins. The materials and energy used for all alternatives are less than 0.02% of the average production or consumption in the U.S. during the same time period. If the spent fuel disposition facility is delayed appreciably, consumption of resources increases severalfold, compared with fuel disposition availability in the year 1985 because of increased basin requirements for interim storage.

The analysis shows that there are no substantial environmental effects arising from radiation whether the policy is implemented or not implemented or whether ISFS or ARB facilities are used. The total whole-body dose to the world population, given in Table VIII-1 (up to 3×10^4 man-rem for the decentralized storage in ARB facilities with the disposition facility delayed to the year 1995), is very small compared with the exposure to the world population from natural radiation sources (about 2×10^{11} man-rem over the same period). The number of radiological health effects in the world population over the operating period and the next 100 years estimated from EPA dose-effect factors varies from 1 to 13 for these alternatives. Health effects 7-a calculated from occupational doses vary from 1 to 19 as shown in Table VIII-1. Health effects to the world population from natural radiation dose over this same period will result in 1.2×10^8 health effects.

C Table VIII-2 summarizes the environmental effects (population and occupational radiation dose commitment, radiological health effects, and accidental deaths) for Alternatives 3 and 4 for disposition beginning in the year 2010. Other effects such as energy, resources committed, materials consumed, etc., were not analyzed for these two alternatives. As indicated above, they were analyzed for Alternatives 1 and 2 and found to be small. The delay of startup of the initial disposition facility to the year 2010, as assumed in Alternatives 3 and 4, results in approximately 91,200 MTU of domestic spent fuel that requires interim storage. The amount of spent fuel transferred to the U.S. Government and stored in ISFS basins in Alternatives 1 and 2 varies up to 72,000 MTU. These other effects for Alternatives 3 and 4 will be proportionally greater. They will still be within accepted limits.

TABLE VIII-1

C Summary of Environmental Effects — Alternatives 1 and 2 (1985 and 1995 Disposition Facility Startup)

	Centralized or Decentralized Storage in ISFS Facilities with Reactor Discharge Basins at Full-Core Reserve — Policy Implemented (Alternatives 1A or 1B)		*Decentralized Storage in ISFS Facilities with Reactor Discharge Basins at Discharge Capacity — Policy Implemented (Alternative 1B), or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basins with Reactor Discharge Basins at Full-Core Reserve — Policy Implemented (Alternative 2B)*	
	Disposition Facility Startup		*Disposition Facility Startup*		*Disposition Facility Startup*	
Effects	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*
Materials						
Concrete, m^3	2.3×10^4	1.2×10^5	6.7×10^3	7.1×10^4	3.0×10^5	6.5×10^5
Lumber, m^3	1.3×10^3	6.1×10^3	3.9×10^2	4.0×10^3	1.8×10^4	3.7×10^4
Steel, tonne	2.1×10^4	1.1×10^5	6.1×10^3	5.8×10^4	1.5×10^5	3.4×10^5
Copper,[a] tonne	3.2×10^1	1.5×10^2	9.5×10^0	9.7×10^1	4.3×10^2	8.9×10^2
Zinc,[a] tonne	5.4×10^1	2.5×10^2	1.6×10^1	1.6×10^2	7.2×10^2	1.5×10^3
Lead,[a] tonne	8.6×10^3	1.1×10^4	8.8×10^3	9.6×10^3	8.8×10^3	1.2×10^4
Depleted Uranium,[a] tonne	4.9×10^2	6.9×10^2	4.9×10^2	5.5×10^2	4.9×10^2	6.5×10^2
Chromium[a] (in stainless steel), tonne	1.3×10^3	5.4×10^3	6.0×10^2	3.7×10^3	3.7×10^3	1.0×10^4
Nickel[a] (in stainless steel), tonne	5.8×10^2	2.4×10^3	2.6×10^2	1.7×10^3	1.6×10^3	4.5×10^3
Energy Resources						
Propane, m^3	5.9×10^2	2.7×10^3	1.7×10^2	1.8×10^3	7.7×10^3	1.6×10^4
Diesel Fuel, m^3	1.7×10^5	2.2×10^5	1.7×10^5	2.0×10^5	3.1×10^5	4.8×10^5
Gasoline, m^3	1.0×10^4	4.7×10^4	3.0×10^3	3.0×10^4	1.4×10^5	2.8×10^5
Electricity, MW-yr	6.5×10^1	1.0×10^3	8.2×10^0	5.0×10^2	1.8×10^2	1.4×10^3
Coal, tonne	4.0×10^5	6.2×10^6	5.4×10^4	3.0×10^6	1.2×10^6	7.6×10^6
E Manpower, man-hour	4.5×10^7	8.5×10^7	3.9×10^7	7.6×10^7	1.1×10^8	1.9×10^8
Radiation Dose Commitment, man-rem						
Worldwide Population[b]	1×10^3	2×10^4	3×10^2	9×10^3	4×10^3	3×10^4
Work Force	1×10^3	5×10^3[c]	8×10^2	4×10^3	6×10^3	3×10^4
Health Effects[d]						
E Worldwide Population	1	10	1	6	2	13
Work Force	1	4[e]	1	3	4	19
7-j Occupational Accidents (nonradiological fatalities)[g]	11	14[f]	11	14	23	42

a. A significant fraction of these materials could be recovered during decommissioning of facilities and recycles, if desired.

C *b.* Whole body dose during the operating period plus the next 100 years. (For comparison, the equivalent dose to the world population from natural radiation sources over the same period is about 2×10^{11} man-rem. This natural dose will result in 120 million health effects.)

c. For Alternative 1B-1, the work force dose commitment is 8×10^3 man-rem.

d. Somatic and genetic health effects, calculated from radiation doses, assuming a linear dose-health effect relation. EPA dose-effect factors were used.

e. For Alternative 1B-1, the health effects to the work force is 6.

7-j *f.* For Alternative 1B-1, the fatalities from occupational accidents are 17.

g. Includes construction accidents.

C

TABLE VIII-2

Summary of Environmental Effects — Alternatives 3 and 4 (2010 Disposition Facility Startup)

	Policy Implemented		*Policy Not Implemented*	
	Centralized Storage (Alternative 3A)	*Decentralized Storage (Alternative 3B)*	*Decentralized Storage (Alternative 4A)*	*Storage in ARBs (Alternative 4B)*
Radiation Dose Commitment, man-rem				
Worldwide Population[a]	5×10^4	5×10^4	5×10^4	9×10^4
Work Force	1×10^4	2×10^4	2×10^4	9×10^4
Health Effects[b]				
Worldwide Population	28	28	28	51
Work Force	6	10	10	62
Occupational Accidents[c] (Nonradiological fatalities)	20	26	26	112

a. Whole body dose during the operating period plus the next 100 years. (For comparison, the equivalent dose to the world population from natural radiation sources over the same time period is about 4×10^{11} man-rem. This natural dose will result in 220 million health effects.)

b. Somatic and genetic health effects, calculated from radiation doses, assuming a linear dose-health effect relation.

c. Includes construction accidents.

C The analysis shows that there are no substantial environmental effects arising from radiation whether the policy is implemented or not, or whether ISFS or ARB facilities are used. The total whole-body dose to the world population, given in Table VIII-2 (up to 9×10^4 man-rem for decentralized storage in ARB facilities with the initial disposition facility delayed to the year 2010), is very small compared to the world population from natural radiation exposure (about 4×10^{11} man-rem over the same period). The number of radiological health effects in the world population over the operating period and the next 100 years varies from 34 to 113 for these alternatives. Approximately half of these health effects are expected to occur in the population within 80 km (50 mi) of facilities. Health effects to the world population from natural radiation dose over this same time period will result in 2.2×10^8 health effects (2.1×10^4 health effects will occur in the 80-km-radius population from natural radiation dose).

7-j The estimated number of deaths in the construction and
operations work force from nonradiological accidents for
Alternatives 1A, 1B, and 2A is the same (11 to 17). Accidental
C deaths for Alternative 2B (Policy Not Implemented, decentralized
storage in ARB facilities) are larger (23 to 42) than for other alternatives for a 1985 or 1995 startup of disposition facilities because of a larger work force. Accidental deaths for Alternatives 3A, 3B, and 4A are the same (20 to 26). Accidental deaths for Alternative 4B (Policy Not Implemented, decentralized storage in ARB facilities) are larger (112) than for other alternatives for a year 2010 startup of disposition facilities because of a larger work force. In all alternatives, the accidental deaths are a small fraction of the annual deaths from occupational accidents in the U.S. (12,500 in the year 1976).

Also, it is concluded that storage of spent fuel in ARB facilities or in centralized or decentralized ISFS facilities and the associated transportation of spent fuel does not impose an unacceptable safeguards risk to the public.

The advantages and disadvantages of not allowing trans-
shipment of spent fuel can be gauged by comparing environmental
effects of Alternative 2B (where no transshipment is assumed
C after ARB storage becomes available in the year 1983) with those
of the other alternatives for a 1985 or 1995 startup of disposition facilities (where transshipment is assumed through the year 2000). (Comparison to Alternatives 3 and 4 should not be made due to differences in fuel flows and length of study between Alternatives 1 and 2, and Alternatives 3 and 4.) The principal advantage of Alternative 2B is the reduction in transportation activities that would result in decreased exposures of about four man-rem to the public and 50 man-rem to transportation workers. The principal disadvantage is the requirement for additional storage basin facilities which result in increased population

exposure of 2000 and 5000 man-rem for 1985 and 1995 startups of the disposition facility, respectively. These increased exposures (resulting from the additional basin capacity provided in Alternative 2B) could be reduced somewhat by adjusting the at-reactor basin capacities to be more in line with that actually needed. However, the assumption of 500 MTU minimum capacity for at-reactor basins is based upon a concept presented by NRC (see Appendix B) and the understanding that additional basins now planned at many reactors will be considerably larger than 500 MTU.

Population and occupational exposures are reduced slightly (0.2 man-rem and 4 man-rem, respectively) if all transshipments to the basins are eliminated (including emergency shipments assumed in Alternative 2B). The analysis in this volume shows that elimination of this transshipping will result in reactor shutdowns equivalent to a loss of 4300 MWe capacity for the maximum year or a cumulative power loss of 17,000 MWe (Table III-17). While this reduction of electrical generating capacity is only a fraction of
C the total available in the United States, it is conceivable that localized shortages could result.

The analysis also shows that the environmental risks from
C major abnormal events and accidents for Alternatives 1 and 2 are very small and essentially the same for the two alternatives. The environmental risks were not determined for Alternatives 3 and 4 but the risks for these alternatives would be proportional to those of Alternatives 1 and 2 corrected for the changes in program size and program duration. The maximum individual doses following abnormal natural events (e.g., tornadoes) and severe accidents (e.g., criticality) that might occur during operation of the facilities are all well below one rem, and the probability of these events occurring is low. The greatest consequences from accidents involve transportation activities in which the shipping
C cask containment is breached. In this accident involving long-cooled spent fuel, the maximum dose to an individual would be about 0.4 rem to the whole body. The annual risk to an individual
8-b from this accident is estimated to be about 1×10^{-5} rem/year. No biological effects of any significance are expected from the accidents analyzed.

In summary, the environmental impacts from all alternatives considered, either from implementing or not implementing the Spent Fuel Storage Policy, are small. The slightly lower resource consumptions and transportation requirements and environmental
C impacts of Alternatives 1B-2 and 2A where reactor discharge basins operate at less than full-core reserve must be balanced against the reduced flexibility in reactor operation and the possibility of forced shutdowns. The shutdowns could lead to the use of higher-cost supplemental power or reduction of electrical power

generation. At-reactor storage increases environmental effects compared with those for ISFS basin storage, because additional storage basins with larger cumulative capacity are constructed and operated. However, the environmental impacts are relatively small compared with available resources and risks from natural radiation sources.

C. Institutional Factors

As discussed, three distinct policies were considered to illustrate the range of possible impacts regarding the storage of domestic spent fuel. They include

1. Acceptance of domestic spent fuel at centralized storage basin(s) (Alternatives 1A and 3A)

2. Acceptance of spent fuel for storage in small, decentralized basin(s) (Alternatives 1B-1, 1B-2, and 3B)

3. No new policy initiatives in this area. This results in privately owned ISFS or ARB facilities (Alternatives 2A, 2B, 4A, and 4B)

Delay in policy implementation could result from

- Licensing process for both new government and private facilities, for newly expanded private basins, and for reracking existing basins

- Licensing process for transportation

- State and local regulatory process for transportation, siting, permitting and rate adjustments

- Ownership arrangement, and

- Other considerations.

The major barrier to any storage facility construction or modification is the perception that such action would result in de facto permanent storage. State and local governments and interested citizens feel that increased onsite storage may serve to diminish the sense of urgency in dealing with waste disposal. Several states have already opposed reracking and new pool construction on this basis.

D. Additional Considerations

D.1 Cask Availability

Spent fuel transportation with both rail and truck casks are considered in this report. If the Spent Fuel Storage Policy is implemented, more truck and rail casks would be required earlier than if the policy is not implemented. The incremental number of casks required earlier are shown in Table VIII-3 for Alternatives 1 and 2, along with the number of years of advanced procurement. If the policy is implemented, the incremental procurement of casks would result in earlier expenditures of monies and earlier facing of cask fabrication problems than if the policy is not implemented. Cask availability was not analyzed for Alternatives 3 and 4 (startup of disposition facility in the year 2010). However, it should be noted that there will be a decreased need for early availability in these alternatives because of a decreased amount of spent fuel shipments in the early years of operation of interim storage facilities.

Casks are fabricated by manufacturers who have the capabilities to handle and machine large parts and who have established quality assurance controls required for certification of casks. Numerous manufacturers have the capacity to fabricate the steel components for the casks. Several manufacturers have the capability of casting the quantity of lead and/or uranium that is needed for large casks. However, fabrication capacity is limited for casting the large number of depleted uranium components required. It is expected that private industry will supply the required casks.

D.2 Safeguards

Since spent fuel contains a large inventory of fission products, it is relatively unattractive and inaccessible to potential subnational misuse. Because of the difficulty of obtaining spent fuel and the radiation risk to those who handle it in makeshift equipment, the probability of a successful attempt to cause a dispersal or a criticality incident is very low. In addition, the level of consequences that could occur from the most credible sabotage scenarios is low and not significantly larger than the consequences that would result from a similar sabotage incident not involving nuclear materials. Property damage resulting from sabotage incidents would consist mostly of localized contamination, which would limit access until cleanup operations could be completed. It is concluded that storage of spent fuel in ISFS or ARB facilities and the associated transportation of spent fuel does not impose an unacceptable risk to the public.

C

TABLE VIII-3

Early Availability of Domestic Casks — Alternatives 1 and 2

Alternative	*Case Description*	*Disposition Facility Startup*	*Year Additional Cask(s) Needed*	*Incremental Number of Casks Required Early*[a]	*Years of Advanced Procurement*
1A	Centralized Storage in ISFS	1985	1983	43	5
	Policy Implemented	1995	1983	49	17
1B-1	Decentralized Storage in ISFS	1985	1983	43	5
	Policy Implemented	1995	1983	49	17
	Full-Core Reserve				
1B-2	Decentralized Storage in ISFS	1985	-	0	0
	Policy Implemented	1995	-	0	0
	Discharge Capability				
2A	Decentralized Storage in ISFS	1985	-	0	0
	Policy Not Implemented	1995	-	0	0
2B	Decentralized Storage in ARB	1985	1983	21	5
	Policy Not Implemented	1995	1983	15	7

a. The maximum number of casks is not required in the first year that casks are required.

REFERENCES FOR SECTION VIII

C

1. Draft Environmental Impact Statement — Storage of U.S. Spent Power Reactor Fuel. USDOE Report DOE/EIS-0015-D, U.S. Department of Energy, Washington, DC (August 1978).

2. DOE Announces New Spent Nuclear Fuel Policy. Press Release, U.S. Department of Energy, Washington, DC (October 1977).

3. Spent Fuel Storage Requirements — The Need for Away-From-Reactor Storage — An Update of DOE/ET-0075. USDOE Report DOE/NE-0002, U.S. Department of Energy, Washington, DC (January 1980).

APPENDIX A

CHARACTERISTICS OF THE ENVIRONMENT OF GENERIC FACILITIES

The characteristics of the environment of generic facilities described in A.1 of this appendix are assumed to apply either to ISFS or ARB facilities. This generic site environment is used as a guide for assessment of the potential environmental effects of storage basin operations, particularly the radiation dose to man.

3-j The proposed 10 CFR 72[1] establishes general design criteria for fuel storage facilities. These criteria define acceptable characteristics of the site and specify design requirements for protection against environmental conditions and natural phenomena. All existing and new storage facilities utilized in the program will be licensed by the Nuclear Regulatory Commission.

A.1 Introduction of Reference Environment

A generic site environment is introduced as a guide for assessment of the potential environmental effects of spent fuel storage, particularly the radiation dose to man. Each generic facility (ISFS or ARB facility) is assumed to be located independently in the reference environment; and the impacts associated with construction, operation, and decommissioning of that facility are assessed against this environment. Although the reference environment is based primarily upon data for the midwestern United States, there is no intent to endorse this particular area for the actual facilities. The center of the reference site is assumed to be about 8 km (5 mi) west of River R and 50 km (31 mi) northwest of a major metropolitan area (City G) in the midwestern state.

A.2 Demography and Land Use

The reference environment is in a region which is mainly rural; the land is used chiefly for farming. Five communities (A-E) with populations of about 1700, 300, 800, 900, and 2500 are within about 16 km (10 mi) of the site. The closest large cities are F (population about 33,000), about 32 km (20 mi) northwest, and G (population of about 1,500,000), about 50 km (31 mi) southeast.

The population within a 16-km (10-mi) radius of the site is about 10,000, distributed as shown in Figure A-1. Within a 16- to 80-km (10- to 50-mi) radius, the population is about 1,700,000, distributed as shown in Figure A-2. These populations and their distributions are expected to increase with time as shown in Figure A-3 (Series II Projection of Population of United States).[2]

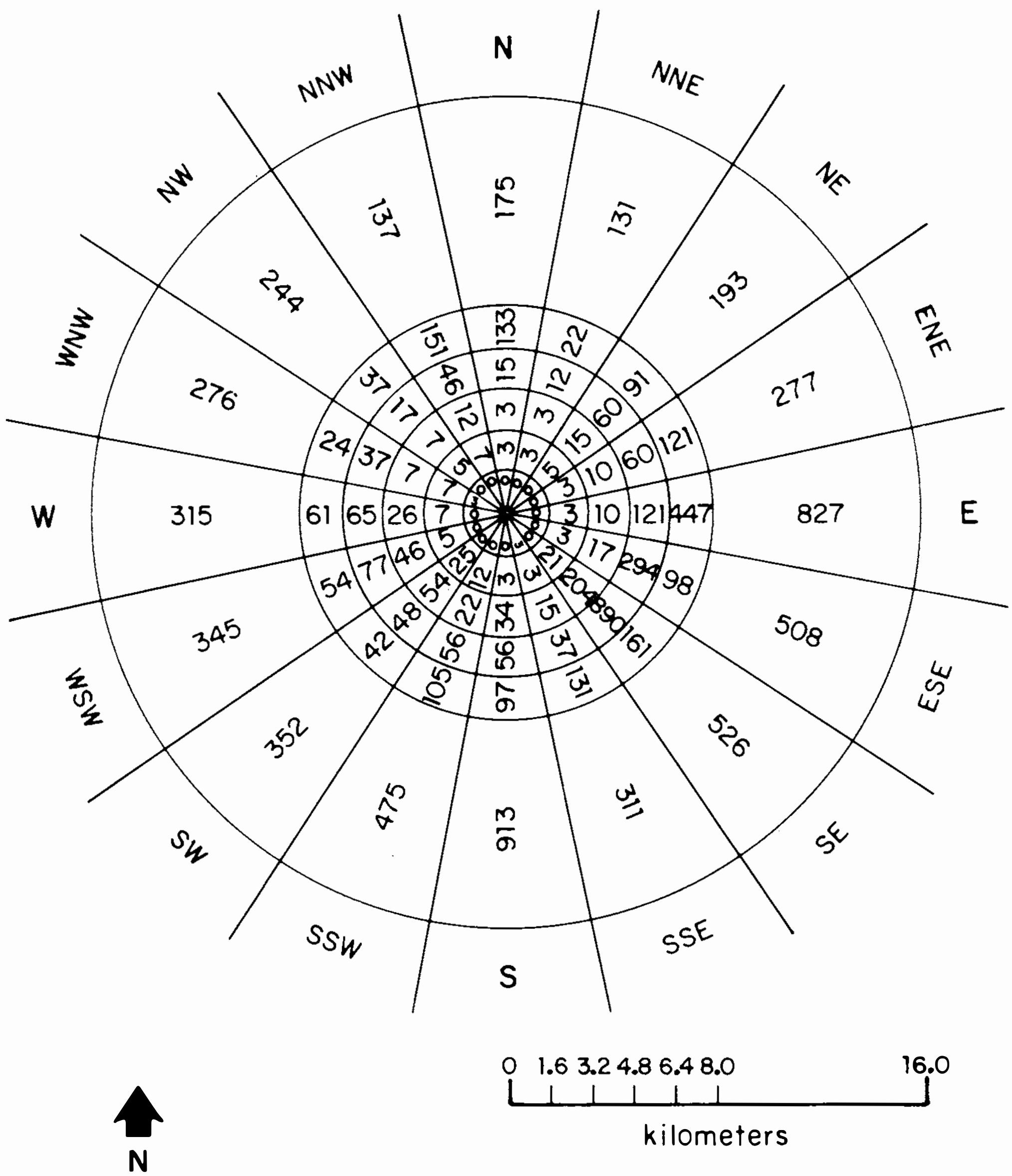

FIGURE A-1. Population in Reference Environment, 0-16 km

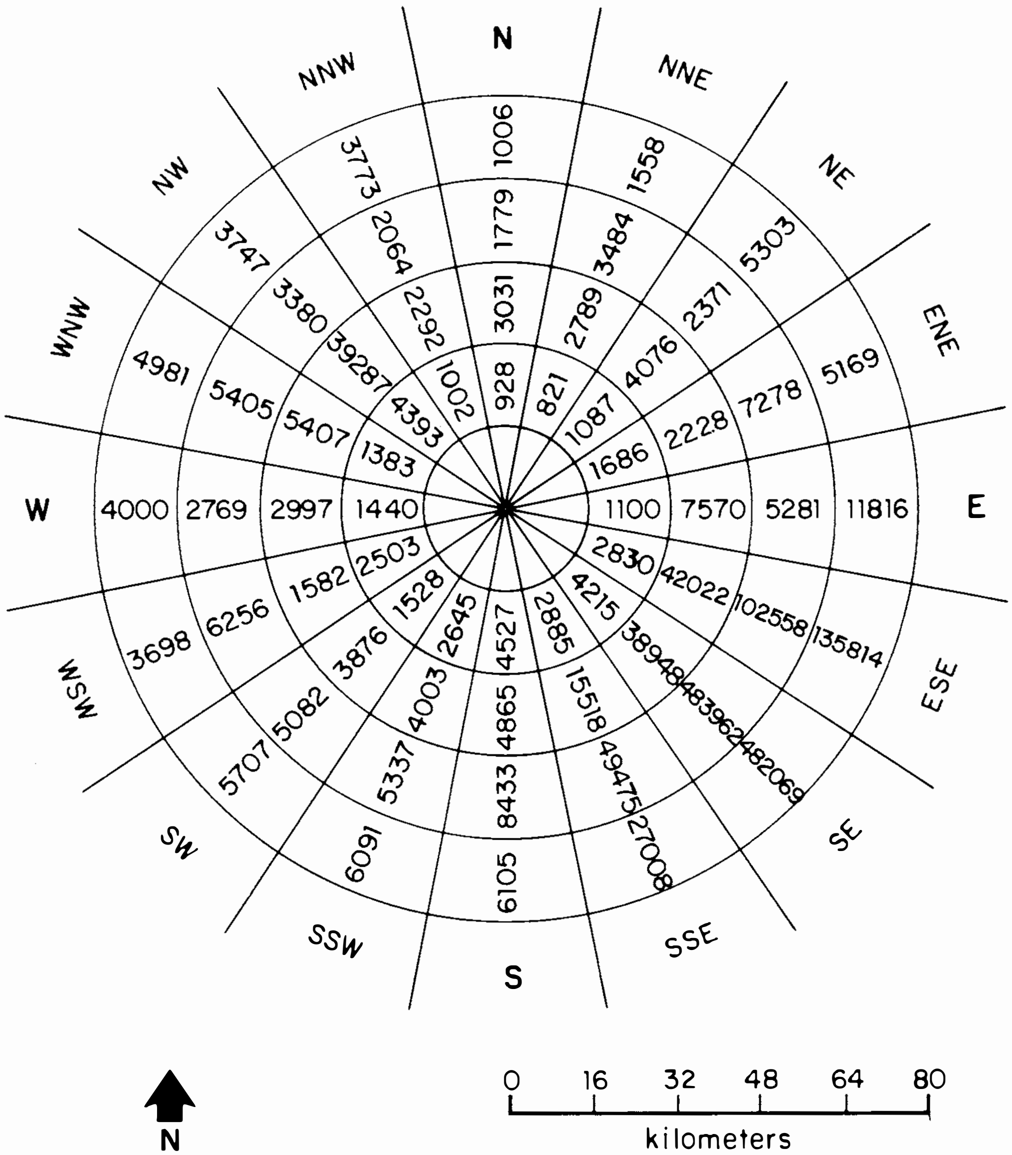

FIGURE A-2. Population in Reference Environment, 0-80 km

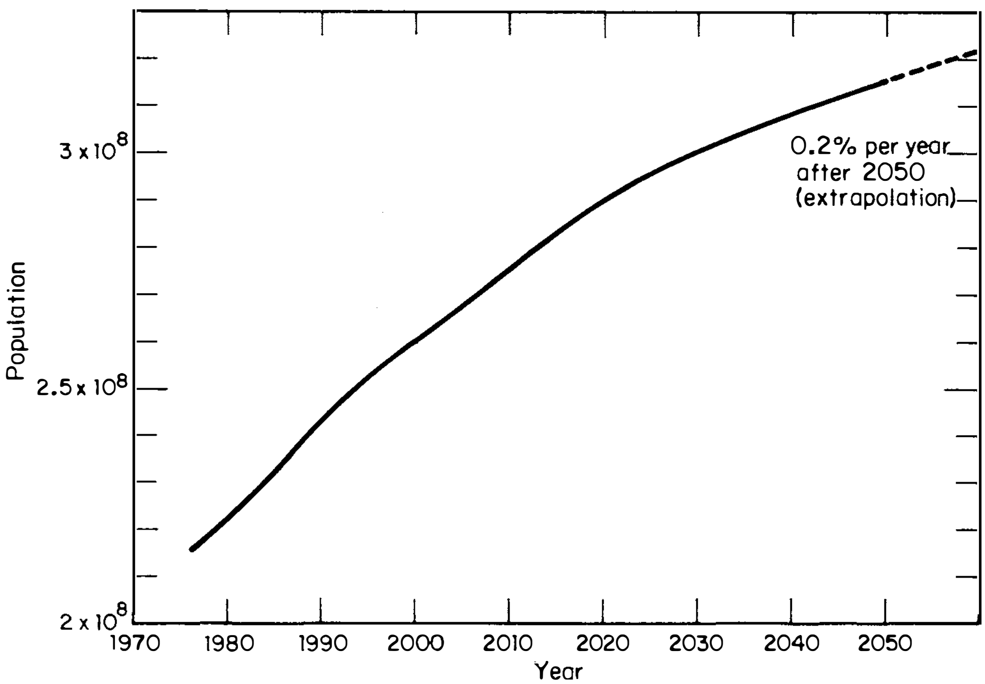

FIGURE A-3. Population Projection of the United States[2]

A.3 Geology

The site area [elevation, 300 m (1000 ft)] is on a flat alluvial terrace [average elevation, 280 m (950 ft)] that comprises the main topographical feature in the vicinity. The upper surface of the underlying rock can support foundation loads up to 73,000 kg/m^2 (147,000 lbs/ft^2). The nearest known geological fault is 37 km (23 mi) southeast of the site with no indication that faulting has affected the site area in the last few million years. Within the last 110 years, only two earthquakes (Intensity V - VI MM) have been recorded. This is a seismic criterion (0.25 g, max.) equivalent to that of the proposed 10 CFR 72.[1] The nearer epicenter was about 130 km (81 mi) north-northwest. For construction of facilities, the design basis earthquake is assumed to have a horizontal acceleration of 0.25 g.

A.4 Hydrology

Large supplies of groundwater are available in the site vicinity. The groundwater table under normal conditions is higher than the river (elevation 276 m); groundwater and runoff drain to R River toward the southeast. Deep groundwater also flows in this direction. The closest public water supply well is the A-city well obtaining water 72 m (240 ft) below ground level.

The average annual flow of R River, about 8 km (5 mi) to the east of the site, is 120,000 L/sec (31,600 gal/sec). The nearest domestic water supply reservoir fed by R River is the G Water Works Reservoir for that metropolitan area.

A.5 Meteorology

The general climate is characterized by wide variations in temperature, scanty winter precipitation, normally ample summer rainfall, and a general tendency to extremes in all climatic features.

The average annual rainfall is about 76 cm (30 in.). About 36 thunderstorms occur each year from May through September. The maximum recorded 24-hour rainfall is 13 cm (5.1 in.).

Annual snowfall averages 110 cm (43 in) with extremes of 15 and 220 cm (5.9 and 87 in.). The frequency of icing due to freezing rain is from one to two times per year; the mean duration of icing on utility lines is 36 hours.

Tornadoes and other severe storms occur occasionally with a maximum recorded windspeed of 160 km/hr (100 mph). The expected frequency of a tornado striking a given point in the area is 5×10^{-4} per year.

Diffusion climatology studies indicate that favorable atmospheric dilution conditions will prevail for normal atmospheric releases in the site vicinity. Table A-1 gives the annual average windspeed, direction, and stability.

TABLE A-1

Percent of Occurrence of Annual Average Windspeed, Stability, and Direction

Wind Speed, m/sec	*Stability Type*	*Wind Direction* NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
1.10	A	0.02	0.00	0.01	0.00	0.01	0.01	0.00	0.02	0.02	0.00	0.00	0.01	0.02	0.00	0.00	0.00
2.50	A	0.10	0.11	0.17	0.12	0.07	0.15	0.11	0.15	0.25	0.21	0.31	0.35	0.32	0.37	0.19	0.26
4.30	A	0.27	0.31	0.21	0.22	0.22	0.30	0.47	0.58	0.40	0.58	0.42	0.41	0.62	0.77	0.62	0.58
6.50	A	0.06	0.07	0.01	0.06	0.25	0.72	0.73	1.38	0.62	0.16	0.15	0.09	0.51	0.64	0.59	0.16
9.10	A	0.00	0.00	0.00	0.00	0.00	0.02	0.32	0.31	0.07	0.00	0.04	0.04	0.10	0.17	0.14	0.02
12.20	A	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.10	B	0.02	0.02	0.02	0.04	0.02	0.02	0.02	0.06	0.01	0.04	0.04	0.01	0.00	0.01	0.00	0.00
2.50	B	0.09	0.04	0.16	0.05	0.12	0.09	0.06	0.15	0.11	0.14	0.12	0.16	0.14	0.16	0.10	0.16
4.30	B	0.19	0.14	0.05	0.14	0.05	0.09	0.14	0.23	0.21	0.19	0.07	0.23	0.16	0.22	0.22	0.12
6.50	B	0.01	0.01	0.02	0.01	0.07	0.07	0.05	0.07	0.02	0.00	0.00	0.06	0.21	0.21	0.17	0.05
9.10	B	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.00	0.00	0.01	0.00	0.11	0.01	0.00
12.20	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.10	C	0.02	0.01	0.04	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.05	0.01	0.02	0.00	0.00	0.04
2.50	C	0.05	0.10	0.04	0.06	0.07	0.07	0.06	0.06	0.12	0.06	0.09	0.10	0.07	0.09	0.09	0.02
4.30	C	0.11	0.04	0.07	0.04	0.07	0.05	0.17	0.12	0.05	0.04	0.02	0.16	0.17	0.22	0.14	0.10
6.50	C	0.02	0.01	0.04	0.01	0.04	0.05	0.04	0.07	0.01	0.01	0.02	0.00	0.17	0.15	0.07	0.06
9.10	C	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.02	0.02	0.07	0.00	0.00
12.20	C	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.10	D	0.19	0.16	0.22	0.04	0.07	0.09	0.07	0.10	0.10	0.14	0.10	0.11	0.07	0.10	0.09	0.23
2.50	0	0.54	0.61	0.85	0.62	0.47	0.46	0.47	0.53	0.32	0.32	0.41	0.67	0.47	0.99	0.80	0.68
4.30	D	0.73	0.64	0.62	1.03	0.94	1.17	0.90	0.86	0.49	0.36	0.36	0.72	1.30	1.65	1.30	0.78
6.50	D	0.21	0.27	0.19	0.46	0.61	0.61	0.37	0.35	0.20	0.22	0.16	0.38	1.24	1.40	0.78	0.73
9.10	D	0.10	0.04	0.00	0.00	0.01	0.04	0.07	0.05	0.02	0.01	0.01	0.16	0.07	0.21	0.10	0.02
12.20	0	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
1.10	E	0.06	0.02	0.11	0.15	0.07	0.20	0.09	0.14	0.11	0.10	0.10	0.12	0.05	0.17	0.06	0.09
2.50	E	0.51	0.35	0.25	0.61	0.57	0.72	0.33	0.36	0.21	0.42	0.52	0.65	0.49	0.75	0.48	0.57
4.30	E	0.27	0.10	0.06	0.38	0.26	0.91	0.69	1.16	0.57	0.49	0.30	0.67	0.64	0.78	0.35	0.22
6.50	E	0.01	0.00	0.00	0.11	0.01	0.15	0.36	0.56	0.30	0.10	0.06	0.05	0.22	0.09	0.02	0.10
9.10	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.20	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.10	F	0.07	0.11	0.11	0.10	0.12	0.06	0.12	0.19	0.10	0.15	0.15	0.21	0.09	0.10	0.20	0.15
2.50	F	0.14	0.22	0.15	0.42	0.40	0.46	0.58	0.65	0.32	0.35	0.35	0.63	0.37	0.67	0.38	0.25
4.30	F	0.00	0.01	0.00	0.02	0.05	0.20	0.30	0.48	0.27	0.14	0.05	0.10	0.04	0.17	0.14	0.01
6.50	F	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.05	0.00	0.00	0.01	0.00	0.06	0.00	0.00
9.10	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.20	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.10	G	0.09	0.04	0.12	0.20	0.11	0.19	0.32	0.31	0.17	0.31	0.46	0.33	0.22	0.20	0.12	0.11
2.50	G	0.05	0.05	0.07	0.14	0.17	0.32	0.65	0.74	0.21	0.23	0.28	0.28	0.15	0.35	0.36	0.11
4.30	G	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.16	0.02	0.00	0.02	0.01	0.00	0.12	0.04	0.00
6.50	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.10	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.20	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

A.6 Terrestrial Ecology

Farming, grazing, and logging have removed most of the original deciduous forest in the region. The facility would mostly occupy land formerly under cultivation. Remnants of the native hardwood forest are found on the larger islands of lakes in the vicinity and along the river. The existence of rare or threatened plant species is not evident.

The numerous ponds, lakes, and swampy areas bounding the site provide nesting areas for waterfowl. Bird hunting in the region is mainly directed at waterfowl.

Some important mammals include white-tailed deer, red and gray squirrels, short-tailed shrews, red-backed and meadow voles, pocket gophers, white-tailed jack rabbits, beavers, and muskrat. Squirrel is the major animal hunted in the region.

The only wildlife considered threatened or endangered that lives year-round within the reference state is the northern greater prairie chicken. Three other forms of threatened wildlife (the southern bald eagle, Arctic peregrine falcon, and prairie falcon) migrate through the state.

A.7 Aquatic Ecology

The ecosystem in the R River near the site is very diverse and is capable of alteration with no apparent damage. Studies of the river have shown the presence of more than 40 species of algae, more than 700 species of invertebrates, and 25 species of fish.

Sizable populations of fish which are not amenable to commercial fishing exist in the river. Although recreational use of the river is limited by lack of public access, a significant sport fishery is in a 50-km (31 mi) stretch of the river below the site and above G city. About one tenth of the fish consumed in the G metropolitan area is from this source.

A.8 Pathways Relevant to Radiological Dose Calculations

Man may be exposed to radiation directly or indirectly by a variety of different pathways. The most important pathway in this volume is the airborne pathway. This pathway includes exposure from radiation of radionuclides released, direct radiation from radionuclides deposited on the ground from these releases, and consumption of foods produced from vegetation contaminated by deposition from these releases. Surface water pathways include exposure from ingesting radionuclides with drinking water, consumption of aquatic foods and foods derived from irrigated vegetation, and direct radiation received during aquatic recreation.

REFERENCES FOR APPENDIX A

1. "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation." U.S. Code of Federal Regulations, Title 10, Part 72 (Proposed 10 CFR 72), U.S. Government Printing Office, Washington, DC (1978).

2. "Projections of the Population of the United States: 1975-2050." U.S. Bureau of the Census, Current Population Reports, Series P-25, No. 704, Table 2 (Series II). U.S. Government Printing Office, Washington, DC (July 1977).

APPENDIX B

INTERIM FUEL STORAGE FACILITIES

B.1 Description of Generic Interim Storage Facility

A concept presented in U.S. Nuclear Regulatory Guide 3.24[1] for a separate facility for storage of irradiated nuclear fuel (i.e., a facility not located at a reactor or fuel reprocessing site) suggests use of water-filled modular basins, with each basin having a capacity of about 500 metric tons of irradiated fuel. This capacity was utilized for the purpose of this appendix for both at-reactor (ARB) or separate storage facilities (ISFS). The basin size may vary for different facilities and is a function of facility safety, economics, and construction considerations. Modular construction allows facility expansion with a minimum of additional support facilities and services.

The ISFS or ARB facilities are designed to protect the fuel cladding against mechanical, chemical, or thermal damage. The storage facility provides for a safe, subcritical arrangement of fuel assemblies and adequate shielding of operating personnel from the fuel assemblies. The fuel element cladding is the initial barrier for confinement of irradiated nuclear fuel during storage. The cladding withstands a far more severe environment in the reactor than is encountered in a water storage basin even though exposure time may be shorter.

At the facility, spent LWR fuel assemblies outside the confines of the shipping cask are handled and stored underwater. The water provides

- An excellent heat transfer medium for removing decay heat from the fuel as well as a substantial heat sink
- A transparent radiation shield that allows visual inspection and direct manipulation of the fuel
- Partial containment of fission product gases and essentially full containment of any particulate radioactive material that may escape from a fuel assembly.

The basins are designed to retain their watertight integrity for all credible accidents, including the design-basis tornadoes and earthquakes. These basins are Category 1 seismic structures and, as such, are designed 1) to resist rupture which would cause excessive loss of water and 2) to support and prevent all massive equipment, such as cranes, etc., from falling into the basins, thus causing damage to the spent fuel during the design-basis earthquake. The water shielding the spent fuel will mitigate the effect of tornadic or other wind-driven missiles.[2]

The facility to store irradiated LWR fuel (Figure III-2) is designed to 1) receive, handle, decontaminate, and reship spent fuel casks; 2) remove irradiated fuel from casks; 3) place the fuel in a storage basin; and 4) cool and control the quality of the water. The facility is also designed for removing spent fuel from storage basins, loading the spent fuel into shipping casks, decontaminating loaded casks, and shipping spent fuel.

The next several sections describe the handling and storage facility. The facility developed is based upon the flow diagram shown in Figure B-1. Additional generic facility description is given in Reference 3.

B.1.1 Cask-Carrier Handling

The receiving, shipping, and holding areas shown in Figure B-1 are unenclosed areas adjacent to the ISFS basin facility. Space is required for at least two days of cask-carrier throughput in the receiving and shipping areas and four days in the holding area. ARB facilities do not require these areas because they can be provided by the adjacent reactor facilities.

The maintenance area of an ISFS facility provides facilities and equipment for maintenance and repair of the casks, carriers, and peripheral equipment. An enclosed area large enough to contain a truck cask-carrier, a rail cask-carrier, and the off-loaded peripheral equipment is required. Maintenance and repair work will normally be performed after fuel has been removed from the cask. Work will be limited to routine maintenance and minor repairs except where more extensive work is required to allow cask processing. This maintenance area is not required by an ARB facility. This function can be provided by the adjacent reactor facilities.

The preparation area is an enclosed work space of standard industrial construction that provides facilities and equipment to prepare the cask-carrier for unloading the cask or for shipping
C | offsite. Space approximately 24 m (80 feet) long and 9.2 m (30 feet) wide is provided for each rail cask-carrier in the preparation area. The preparation area also serves as an air lock to control air leakage into the cask processing and fuel storage building.

B.1.2 Cask Processing

The structure housing the cask processing area for either ISFS or ARB facilities is constructed of heavily reinforced con-
E | crete to a height of 7.6 m (25 feet) above pool water level. The additional structure [to a height of about 18 m (60 feet)] and roof are constructed of insulated metal and designed to withstand

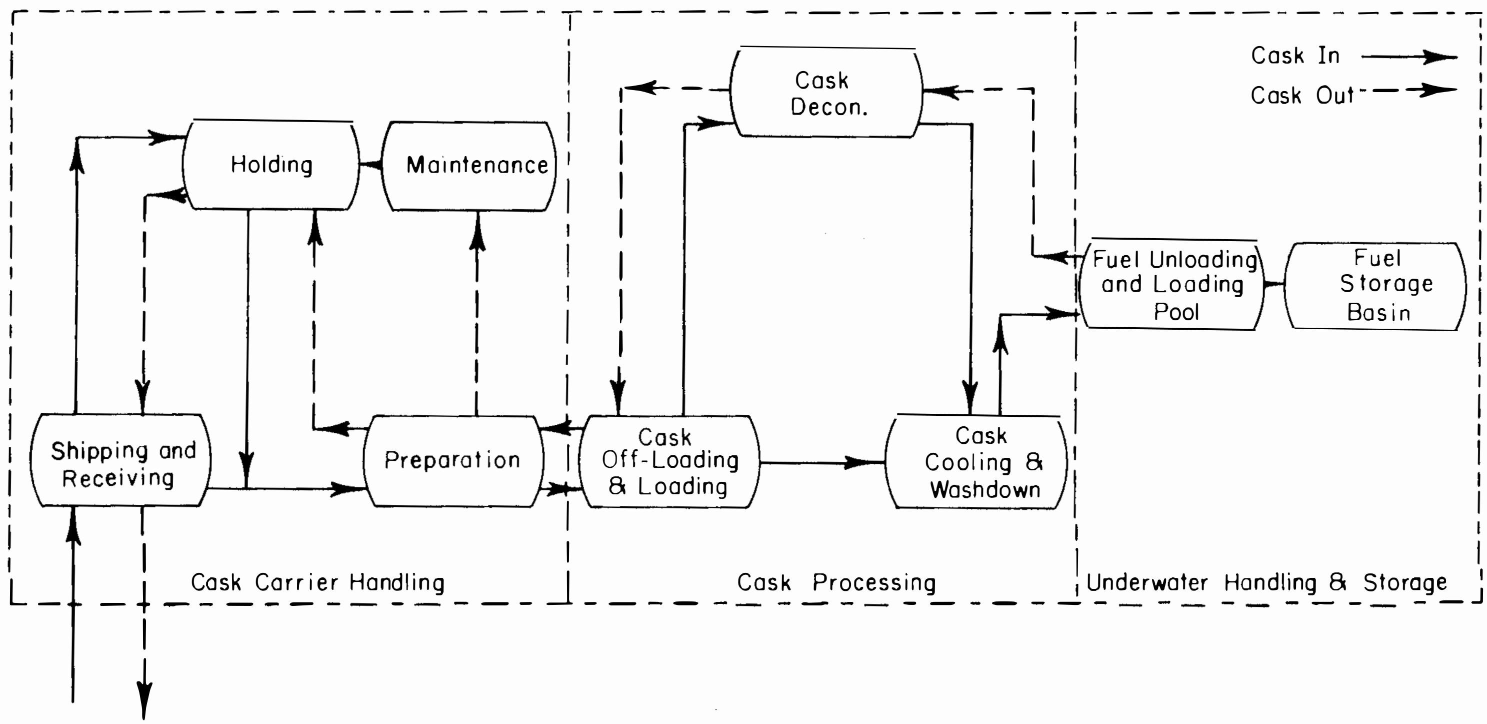

FIGURE B-1. Spent Fuel Handling and Storage the 100-year recurrent wind but not the design basis tornado. An overhead crane, with a load capacity of approximately 113 MT (125 tons), is provided for all cask transfers. Two cranes are required for facilities designed for receiving rates in excess of 1500 MTU/year.

The cask-processing times assumed in this volume are based upon experience at the General Electric Morris Facility. The expected and upper limit values from a log normal distribution of the process times are shown in Table B-1.

The minimum number of handling locations was determined for various cask throughputs by using the processing time described above. These handling locations are given in Table B-2. The calculated number of handling locations was based on the processing of either truck or rail casks.

The limiting size for a single handling facility is judged to be about 3000 MTU/year for the assumed rail/truck split. Larger facilities would be hampered by limitations on the movement of cranes handling both casks and fuel baskets, by difficulty in achieving a layout for material flow, etc. For throughputs larger than 3000 MTU/year, multiple facilities would be constructed, i.e., for 4000 MTU/year throughput, two 2000 MTU/year facilities.

The layout of a facility for receiving up to 2500 MTU/year and storing 3000 MTU is shown in Figure B-2. The number of handling locations would be changed to satisfy different receiving rates (Table B-2). Storage basins with a capacity of 500 MTU each can be added as required.

B.1.2.1 Cask Offload-Load Area

The cask offload-load area provides a space 30 m long by 9.2 m wide (100 ft long by 30 ft wide) for each cask-carrier. After the cask is removed from the carrier, the carrier is washed, if necessary. Wash water is collected in a hold tank for subsequent radiation level checks to determine if additional treatment of the water is required.

B.1.2.2 Cask Cooling and Washdown

The cask cooling and washdown facilities and equipment will occupy a below-grade area of 5.5 m by 5.5 m (18 ft by 18 ft). These facilities and equipment are provided for each handling location to gain access to the cask. The floor is designed to direct wash water to a collection sump. A special energy-absorbing pad

TABLE B-1

Cask Process Times

Area	Time, hr LWT Cask,[a] Truck: Expected	LWT Cask,[a] Truck: Upper Limit[b]	GE IF-300 Cask, Rail: Expected	GE IF-300 Cask, Rail: Upper Limit[b]
Preparation-Offload	4.0	8.0	4.9	9.1
Cooldown	4.0	8.0	4.9	9.1
Fuel Unloading	2.8	7.2	7.0	11.4
Decontamination	3.3	11.0	14.0	22.4
Reload-Delay, Preparation-Offload	4.0	10.5	6.1	13.3
Turnaround Time	18	45	37	65

a. NFS-4 (Reference 3).

b. Upper Limit includes 95% of all values.

TABLE B-2

Minimum Number of Cask Handling Locations at a Fuel Storage Facility

Spent Fuel, MTU/year[a]	500	1000	1500	2000	2500	3000
Casks/day, Rail	0.4	0.8	1.1	1.5	1.8	2.2
Casks/day, Truck	1.4	2.7	4.0	5.4	6.7	8.0
Handling Location	*Number*					
Preparation Area and Cask Offload-Load Area	1	2	2	3	4	4
Cask Cool and Washdown Areas	1	1	1	2	2	2
Fuel Unloading Pools	1	1	1	2	2	2
Cask Decontamination Area	1	1	2	2	2	3

a. Assumes 300 days' operation of the facility at full capacity.

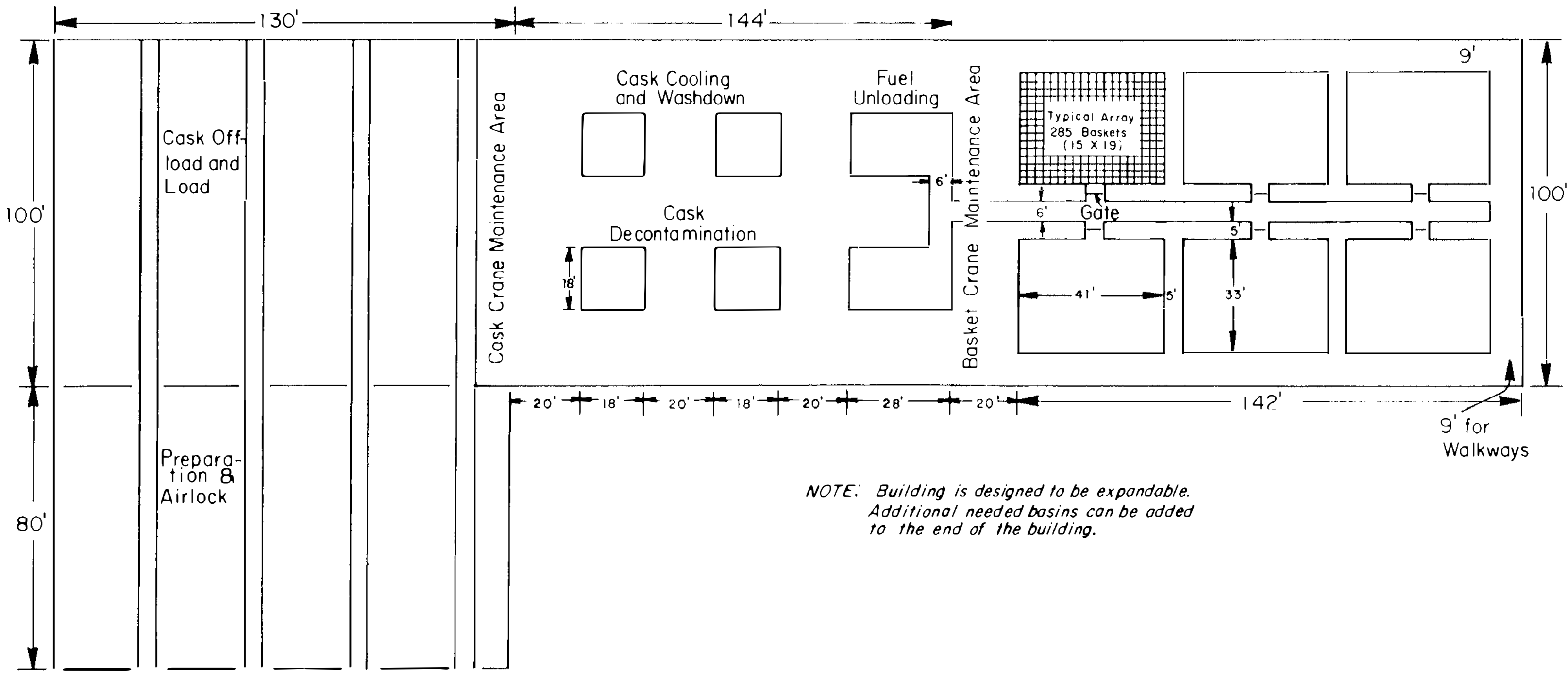

FIGURE B-2. Cask and Fuel Handling Facility — Fuel Storage Basin Layout protects the cask and the floor if a cask is dropped. Design prevents tipping of a cask while it is being unloaded or loaded. All piping in the area is protected against damage from inadvertent contact with a cask.

Casks are washed to remove the road dirt before transfer to the fuel unloading pool. Wash water is collected for treatment. After washdown, the cask is vented to the facility off-gas system, and the primary coolant is checked for temperature and radioactivity.

B.1.2.3 Cask Decontamination

The decontamination area provides facilities and equipment to reduce surface contamination of casks to acceptable levels. The area is below grade. A space of 5.5 m by 5.5 m (18 ft by 18 ft) is provided for each cask to allow access to the cask for decontamination. The floor is designed to direct wash solutions to a collection sump. A special energy absorbing pad is provided. Movable work platforms provide access to the top and sides of the cask.

B.1.3 Underwater Handling and Storage

The structure housing the pools for underwater handling and storage of the fuel is heavily reinforced concrete above grade to a height of 7.6 m (25 ft) above the pool water level. Additional superstructure and roof are constructed of insulated metal designed as previously described. All water-filled pools are below grade and lined with stainless steel. Pool or basin water is maintained at a temperature of $\leq 40°C$ to reduce loss from evaporation and to retard algae growth. The radioactivity in this water is maintained at $\leq 2 \times 10^{-4}$ Ci/m^3.

The pools and basins are provided with a high-flow emergency water supply to maintain water level as a backup if the normal makeup system is insufficient. Piping into and out of the pools and basins is installed in such a manner as to prevent draining or siphoning below safe levels.

B.1.3.1 Cask Unloading Pool

The cask unloading pool provides facilities and equipment for underwater transfer of spent fuel from the shipping cask to storage baskets holding either nine BWR assemblies or four PWR assemblies. The stainless steel baskets are designed to maintain critically safe spacing of the fuel assemblies.

Each unloading pool provides space for one cask in the vertical position, fuel storage baskets with protective support racks, and a shelf to store the cask lid. A crane with a load capacity of ten tons is used to remove the cask lid and transfer fuel assemblies from the cask to the storage baskets. A separate crane is used to transfer loaded baskets to the storage basins. The pool and basin depth are sufficient to maintain adequate radiation shielding of the fuel assemblies as they are withdrawn from the cask. Each unloading pool covers an area of about 46 m^2 (500 ft^2) and is about 15 m (50 ft) deep. A special energy absorbing pad protects cask and pool integrity in the event a cask is dropped.

B.1.3.2 Storage Basins

Each storage basin is sized to hold about 500 MTU of fuel assemblies. The storage baskets used in the basin hold either 1.69 MTU in BWR assemblies or 1.84 MTU in PWR assemblies. With the expected distribution of two PWR assemblies to one BWR assembly, 168 PWR baskets and 112 BWR baskets are used in each basin. Each side of the square storage basket is 61 cm (24 in. long). The baskets are stored in safe geometry racks attached to the pool floor. A space of about 124 m^2 (1340 ft^2) is required for each 500 MTU. Aisles are provided for access to pool areas; however, in order to remove inner baskets, it is necessary to move outer baskets to create an access aisle. Depth of each storage basin is about 9 m (30 ft). Total volume of the basin is 1140 m^3 (40,200 ft^3). Volume of water in a fully loaded basin is 1010 m^3 (35,600 ft^3).

B.1.3.3 Transfer Aisles

Transfer aisles are provided in either ISFS or ARB facilities for moving storage baskets from fuel unloading pools to storage basins. These aisles are 1.8 m wide and about 9.2 m deep (6 ft wide and about 30 ft deep) to provide at least 3.7 m (12 ft) of water shielding above the fuel during movement through the aisles.

B.1.4 Support Systems

The ISFS or ARB facilities have support systems which dissipate the heat, control the quality of water in the pools, ventilate the building, treat the radioactive waste generated, and provide services such as electricity and water. In addition to these process-related systems, the storage basin facility includes support facilities and activities not directly associated with spent fuel handling. These facilities include a chemical laboratory, personnel monitoring stations, a counting room, a change room, a maintenance shop, storage rooms, and office space.

The support systems are housed in a building which occupies an area about equal to that of the fuel handling and storage building and is 6.1 to 7.6 m (20 to 25 ft) high. The structure that houses systems for treatment of pool water and radioactive wastes is assumed to be an integral part of the storage facility and is constructed to withstand design basis earthquakes and tornadoes (Figure B-1). Waste treatment areas of the building where the potential for contamination is high are lined with stainless steel. All leakage from this area is diverted to a collection sump that is returned to the waste evaporator.

The H&V systems and personnel offices (shown in Figure III-2) are housed in structures of standard industrial construction.

Waste Management for the ISFS or ARB Facilities. Releases of radionuclides to the environment from the generic facility are controlled by the off-gas system and the ventilating air system. The off-gas system collects gases from the cask venting and cooldown and the radwaste treatment systems and routes it through an off-gas scrubber, an iodine absorber, and high efficiency (HEPA) filters. The off-gas system is designed to remove most of the iodine and particulates. The ventilating air from the remainder of the basin system is released directly to the environment. Both the treated off-gases and air from the normal building ventilation are released to the environment through the 45-m (150-ft) high stack.

No aqueous releases containing radionuclides are expected from the ISFS basins or ARB facility. Heat removal is accomplished by a primary and a secondary cooling system. Heat is transferred from the process equipment to the secondary cooling water systems by heat exchangers. This arrangement provides an effective barrier between the environment and potential leaks in the process equipment. The basin water cleanup system incorporates deionization facilities to remove any radionuclides.

The major volumes of liquid and semiliquid wastes requiring treatment are filter sludges, ion-exchange regeneration solutions from the water treatment system, and water-detergent solutions used to decontaminate casks and equipment. These liquids or semiliquids are sent to the evaporator where they are concentrated into a slurry. The slurry is sent to the waste solidification system for solidification with an agent such as cement or bitumen. The water removed during evaporation is released to the atmosphere through the facility stack.

The solid radioactive wastes include ventilation filters, rags, clothing, plastic, paper, wood, rubber, failed small equipment, and similar items. The volume of the material is reduced by incineration and/or compaction. This waste is then packaged in 210-L (55-gallon) drums and immobilized before being shipped to the land burial site or to the geologic repository.

All radionuclides will be isolated from normal domestic and storm water effluents by facility design. Normal domestic water releases from the ISFS facility will be treated either onplant or in some regional or municipal sewage disposal facility. If treated onplant, land application will probably be used following secondary treatment. If treated offplant, ISFS facility domestic effluents will meet all pretreatment standards of the Federal Government (40 CFR 128) and state and local governments. Storm water will be routed as discussed in Section 208 of the Clean Water Act. Storm water effluent from these facilities will utilize the best management practices available to minimize adverse effects of these discharges. Facility design and area grading will incorporate concerns specified in Executive Order 11988, "Flood Plans, Management Directive." Specifics of implementing these controls depend upon local siting requirements and will be discussed in more detail in site specific-environmental impact statements prepared for specific facilities.

B.2 Environmental Effects

B.2.1 Construction

Potential effects of construction on ecology, surrounding communities, and land and water use are considered for the ISFS facilities. The discussion incorporates material from a similar section in ERDA-77-75.[4]

B.2.1.1 General Description

The site for an ISFS facility would cover an area of about 405 hectares (1000 acres). This area does not include the space external to the actual sites for transmission lines and for access to highways and railways.

The ARB facility is assumed to be located adjacent to the reactor on the land area maintained for the reactor. Where several reactors are adjacent, a single ARB will be constructed in a central location. In all cases, the ARB will be located so that transport of spent fuel between the reactor discharge basin and the ARB facility will be on utility controlled lands that exclude public thoroughfare.

While the facilities are under construction, some land and water areas will be disturbed and modified where permanent structures are to be located and where other space is used for temporary access, storage of materials and equipment, and disposal of excavated earth. The extent of dredging water areas and clearing, leveling, and filling of land areas depends upon the particular site. Special precautions will be taken to minimize erosion, siltation, and destruction of plants and animals during construction and during the interim period before the disturbed areas are stabilized.

Depending upon the particular facility and its location, construction may have minor to severe social, political, and economic impacts on surrounding communities and existing services. Nonbeneficial effects can be mitigated by judicious site selection and siting negotiations with local jurisdictions and utilities.

B.2.1.2 Effects on Land Use

The primary construction impact on land use occurs where permanent structures are located and where adjacent areas are used for access, storage, office space, and parking. Including temporary construction areas, about 12 to 16 hectares (30 to 40 acres) will be modified for either an ISFS or ARB facility. A secondary construction impact on land use can occur where erosion of exposed areas has the potential for siltation of adjacent aquatic systems. Erosion control measures recommended in Federal agency guides[5,6] will be followed by: 1) limiting vegetation removal to an absolute minimum, especially along stream and river banks; 2) selecting proper sites for excavation-spoil stockpiles; 3) limiting the steepness of inclines; 4) minimizing traffic on the construction site, particularly during critical periods such as spring thaw; 5) early stabilizing and replanting of exposed soils; and 6) providing runoff channels and settling areas to collect and settle surface water runoff before releases to bodies of natural surface water.

The site-specific assessment of the probable impact of committing 405 hectares (1000 acres) for an ISFS facility will deal with the site specific factors. These include:

- Previous or potential land use
- Presence or absence of historical, archaeological, or cultural resources

- Need for offsite facilities.

The ARB facilities do not require the same considerations since they will be located adjacent to the reactor on land currently occupied by the reactor sites.

B.2.1.3 Effects on Water Use

Water use during construction of a facility would average about 60 cubic meters per day (16,000 gallons per day). This use of water would account for a small fraction of the flow of 120 m^3/sec (2700 million gal/day), in R River (Appendix A), or a small percentage of the available groundwater supply in many areas of the United States. In addition to direct consumption, construction operations can temporarily affect water quality and availability in the site area.

Excavations for foundations of major structures often require extensive dewatering: groundwater entering the excavation is pumped out to the surface water. Depending upon the local groundwater recharge, this dewatering may temporarily lower the water table in production wells in the vicinity or may affect flow gradients in the groundwater in other ways, thus affecting the quality of groundwater. Careful attention will be given to the condition of the water to be disposed of during the dewatering process. Due to the buffer area around the construction site, no effect on the groundwater table is expected from the construction site.

B.2.1.4 Effects on Ecology

Changes in the local ecology are expected during the disruptions accompanying the construction activities, with reversal of some changes and restoration to a new equilibrium after completion of these activities. For birds and fish, permanent impacts can be lessened by providing bypass routes or feeding stations for migratory species. For trees and other vegetation, carefully controlled procedures can minimize effects during construction and maximize recovery.

Clearing of wooded land will result in a loss of wildlife habitat. During such clearing and construction, animals will seek shelter in adjacent wooded areas; however, there is likely to be increased mortality among displaced animals. Some foraging species may be benefited by this activity as new shrubs and low brush develop from natural regeneration.

The areas on either site that are not used for permanent facilities can be reclaimed by landscaping and reseeding. Such measures minimize the long-term impact on terrestrial biota in the area.

The major potential for adverse impacts on aquatic ecosystems is associated with an increase of dissolved and suspended solids and siltation in local surface waters resulting from runoff of eroded soils in construction areas. Runoff with high organic content (such as sewage) can exert a high oxygen demand and lead to depletion of oxygen in the sediments and even in the water column. Hiding places and food supplies for fish are adversely affected by siltation destroying weed beds and benthic organisms. Siltation can increase egg mortality by smothering of eggs or lowering the amount of available oxygen.

The benthic community structure is strongly dependent upon the type of substrate available, which is changed by siltation. Benthic organism productivity is also influenced by turbidity and available oxygen. State and local standards and regulations will provide guidance in minimizing the effects of siltation from construction runoff. Evaluation of the potential problems will be considered in each site-specific EIS.

B.2.1.5 Effects on Surrounding Communities

B.2.1.5.1 Physical

B.2.1.5.1.1 Air Pollution

The air polution potential during construction should be significant only in the immediate vicinity of the construction activity where dust must be reduced to an acceptable level, as by frequent spraying of disturbed surfaces.

B.2.1.5.1.2 Traffic

Construction of an ISFS or ARB facility will cause a significant increase in truck traffic around these sites. Traffic control measures would be implemented as required to control truck traffic and ensure safe operations in the vicinity of communities, intersections in rural areas, and school bus pickup points.

Construction workers will also increase the traffic in the area. Special efforts are required to prevent an increased number of accidents during the period of peak construction. Carpooling will be encouraged to reduce local traffic, conserve fuel, and reduce vehicular emission pollutants.

B.2.1.5.1.3 Noise

Noise levels during construction of an ISFS or ARB facility will be of the same magnitude as those for any similar construction project. The estimated level at the property line during the noisiest phase is about 60 dbA; however, if explosive blasting of rock is required, peaks about 98 dbA would be expected. The anticipated human response to such blasting is a little annoyance, no complaints. Construction noise levels should be monitored for compliance with all applicable (OSHA, EPA, state, and local) regulations regarding noise abatement.

B.2.1.5.1.4 Population Displacement

The site for an ISFS facility is most likely to be rural and located on the fringe of a metropolitan region as shown in the reference environment (Appendix A). On the basis of the population density in this reference environment (606 people within 4.8 km), about 34 people will be displaced from each ISFS basin site area. The actual site selection process will include consideration of ways to minimize displacement of the local population.

Construction of ARB facilities should have no population displacement effect because this effect has already taken place during acquisition of the land and construction of the reactor(s) at the site.

B.2.1.5.2 Economic

The economic impact of facility construction can be adverse or beneficial depending upon the specific situation. Temporary adverse effects will usually be offset by longer-range benefits.

Peak employment during the construction phase will be about 1100 persons for an ISFS facility and about 400 people for an ARB facility. The economic impact of the facility felt by the local community will be much greater during the construction period than during the operating period (about 60 to 180 employees).

The employment during the construction phase can have a significant impact on any local area, particularly small communities such as A-E in the reference environment (Appendix A). The impact will vary from community to community, depending upon the local economic base. A significant portion of the labor force may be recruited from outside the immediate area because of special skills required. Migration of workers and their families (about 2 to 3 thousand persons), together with those individuals providing support services, will affect the economy of the area. The employment of a large migratory labor force can strain existing public and private services and facilities unless advance plans are made for handling such an influx of people.

The decline in employees at either an ISFS or ARB facility following the construction phase can also have a noticeable effect on local businesses and services. If the operating force disperses throughout more distant larger cities and a metropolitan region, the decline in the economic bases of the immediate local communities after construction may be greater than if the operating staff chooses to cluster about the site.

B.2.1.5.3 Political

B.2.1.5.3.1 Local Government

During the siting phase, all applicable permits will be obtained from the various local agencies, the tax structure will be discussed with local officials, and any problems that arise between the facility owner and the local jurisdiction will be discussed, including discharges to municipal sewer systems, impact grants for schools, hospitals, etc.

B.2.1.5.3.2 Other Political Considerations

Federal and state licenses and permits will also be obtained and their regulations followed. Hearings will be held to present positions and arguments. In all these areas, a continual ongoing interaction, from the time a site is approved until the operation of the facility, is needed between the facility owner and state and Federal officials.

B.2.1.5.4 Services

B.2.1.5.4.1 Schools

The adequacy of the existing school system to accommodate the influx of children of the construction workers and service employees will have to be analyzed. Depending upon where a spent fuel facility is located - in, near, or distant from a metropolitan area - new school buildings or temporary classroom facilities may have to be made available. Due to the number of construction workers coming to the site, the school system may be inadequate to handle the expected influx of students. With a peak of 1100 construction workers for an ISFS facility or 400 for an ARB facility, each having an average of 1.75 children, an addition of 1900 students to a school district is possible for an ISFS facility or 700 for an ARB facility. Assuming this school district to be at the 16-km (10-mi) radius surrounding the generic facility [reference environment (Appendix A)], it would have a student population of 2200 increasing to a maximum of 4100. School facilities would have to be expanded nearly twofold. The effects of ARB facilities would be lower.

B.2.1.5.4.2 Water and Sewage

During construction, adequate water and sewer facilities are needed for the workers. Availability of these services is a factor in the siting process. If such services are not already available, new services will have to be provided either by building new facilities or by contracting with a nearby local jurisdiction for use of its facilities.

B.2.1.5.4.3 Solid Waste Disposal

The availability of solid waste disposal is also a factor in the siting of a spent fuel storage facility. The development of new disposal facilities and the extent to which such development should be permitted or controlled is the responsibility of the disposal plant operator and state and local authorities.

B.2.1.5.4.4 Utilities

One of the factors to be examined when choosing a site is the ability of the existing electric power system to deal with the increased demand by the new facility and influx of workers into the area. The electrical power demand will range from about
C 0.8 MW for the smallest facility (500 MTU) to 12 MW for the largest facility (18,000 MTU).

B.2.1.5.4.5 Public Health and Medical Facilities

Construction and operation of the facilities considered in this volume will cause relocation of segments of the population. Relocation of medical facilities may be required. Need for medical facilities and teams during construction is greater than during the operating period because of 1) an increased number of workers during construction and 2) the likelihood of accidents occurring during plant construction, which would not occur during plant operation.

Within any local community, there is a need for public health services and specialized clinical facilities. Where these medical services are not currently available, they may be developed, depending upon the anticipated case load and the short- and long-range needs of construction and operating workers - and their families.

B.2.1.5.5 Aesthetic Effects

The specific location of facility construction is a primary factor in determining the aesthetic effect at the site. The facility will be visible from certain angles, although it may be hidden by high bluffs, trees, and other foliage. Adverse aesthetic impact caused by erosion, dust, construction debris, heavy equipment, earth movement, construction buildings, and unadorned partially completed structures will be minimized.

B.2.2 Operations

This section describes the environmental impact of operation of the ISFS or ARB facilities. These impacts consist primarily of

- release of radionuclides to the environment
- discharge of nonradiological material to the environment
- discharge of heat to the environment either as water vapor, combustion gases, or by direct transfer, and
- consumption or use of raw materials.

The environmental effects in this section in general are the total effect for each alternative considered even though several widely separated ISFS or ARB facilities may be involved. The only exception to this is the radiological dose commitment to the hypothetical individual who receives the maximum dose; this commitment is based upon releases from a single site. The environmental releases for each alternative have been compared in Section III of this report.

Table B-3 briefly describes the facilities used for each alternative considered in this report.

TABLE B-3

Description of Storage Basin Facilities for Each Alternative

Disposition Facility Startup[a] →	*Centralized Storage in ISFS Facilities — Policy Implemented (Alternative 1A)*		*Decentralized Storage in ISFS Facilities — Policy Implemented (Alternative 1B-1)*		*Decentralized Storage in ISFS Facilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*
Total Storage Capacity, MTU	6000	54000	6000	54000	500	24000	23500	65000
Total Operations Personnel	150	510	110	990	60	440	2480	5300
Number of ISFS or ARB Facilities	1	3	1	9	1	4	45	93
Storage Capacity, MTU/site	6000	18000	6000	6000	500	6000	500[b]	500[c]
Design Receiving Rate Cask Site, MTU/yr	2500	2500	1000	1000	500	1000	500	500
Years of Operation	13	28	13	28	10	29	7	24

a. Disposition facility startup beyond the year 2000 is possible (see Section III of this volume).

b. Two of the 500 MTU basins are expanded to 1000 MTU.

C *c.* Thirty-four of the 500 MTU basins are expanded to 1000 MTU, and three are expanded to 1500 MTU. In all, there will be 59, 31, and 3 facilities constructed with 500, 1000, and 1500, respectively, MTU storage capacities.

B.2.2.1 Radiation Effects During Normal Operation

In this section, the releases of radioactive materials to the environment from routine operation of ISFS or ARB facilities are assessed in terms of dose commitment to a hypothetical individual living near the facility site and receiving the maximum dose, to the population living within 80 km (50 mi) of the site, to the population of the U.S., and to the population of the world. Dose estimates for the maximum individual are for the year of maximum release of radioactive materials to the environment and also, cumulatively, for the amount of fuel stored in an ISFS or ARB facility for the entire period of basin operation. Dose estimates for the population groups are for the entire period of operation plus 100 years to include persistent effects of released radionuclides. Also included in this section are estimates of occupational radiation exposure and a discussion of radiation effects on the biota other than man.

B.2.2.1.1 Summary of Assumptions and Models

B.2.2.1.1.1 Siting and Meteorology

Each ISFS basin is assumed to be located on a 405-hectare (1000-acre) site with a distance of 0.8 km (0.5 mi) between the basin and the site boundary. Releases of radioactive materials from the ISFS basin to the atmosphere are through a 45-m (150-ft) exhaust stack. Relative concentration factors ($\overline{\chi}/Q$) for this release height are 5.7×10^{-9} sec/m^3 (population weighted) for the 80-km (50-mi) radius population (undepleted cloud). A deposition velocity of 1 cm/sec is assumed for radioiodine and particulates. Dispersion assumptions used for calculating doses to the eastern U. S. population and to the world population are discussed in Reference 3.

Each ARB facility is assumed to be adjacent to a reactor and within the reactor site exclusion area. This area differs for each reactor. Figure B-3 shows the distance to the plant perimeter for operating reactors in the U.S., based upon information contained in References 7 through 9. As can be seen from Figure B-3, the median value for the distance to the plant perimeter is about 0.8 km (0.48 mi) or essentially the same value as used for the ISFS. Thus, for the ARB facility, radiation effects from normal operations were made by assuming the distance between the ARB and the site boundary to be 0.8 km (0.5 mi) as used for the ISFS. The other values described in the previous paragraph were also assumed.

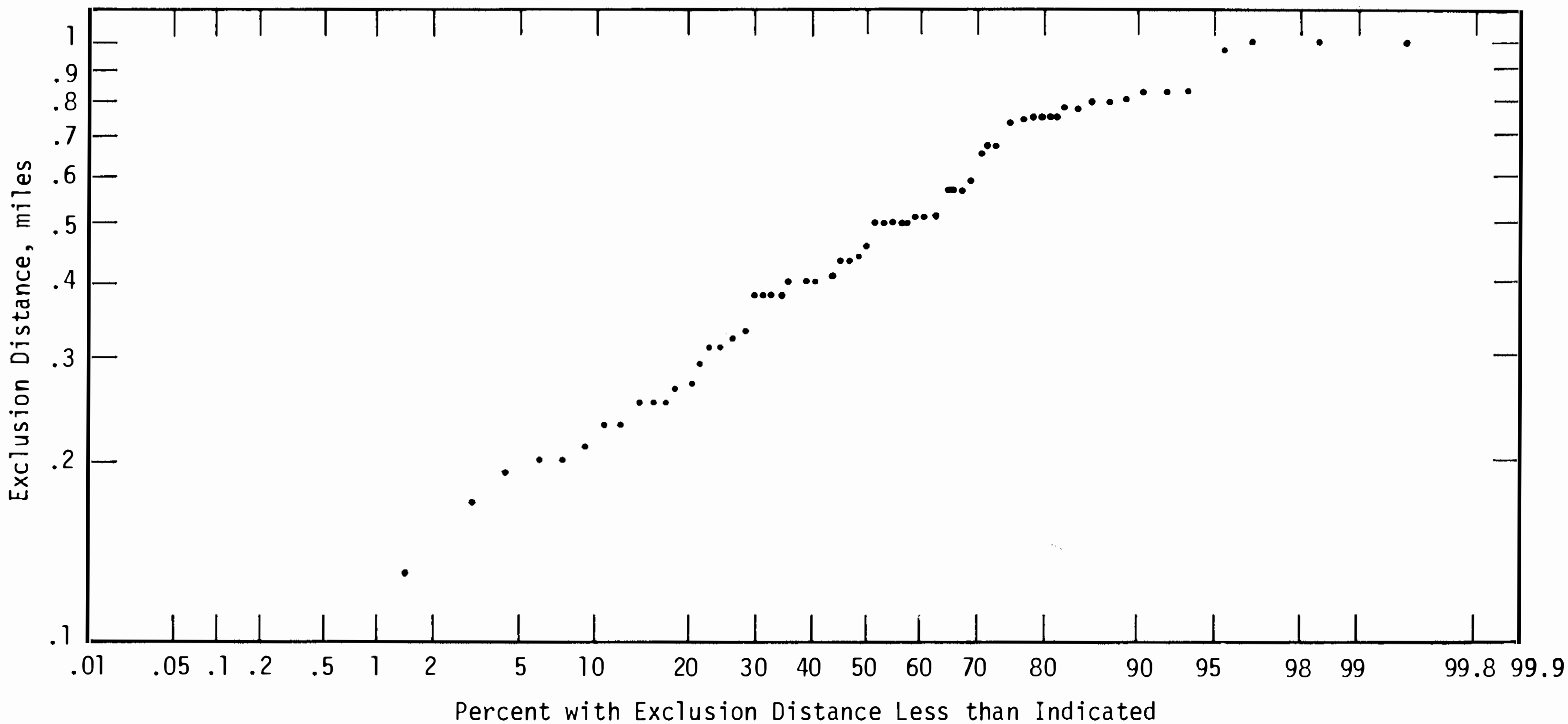

FIGURE B-3. Distance to Plant Perimeter for Operating Reactors

B.2.2.1.1.2 Population Distribution

The population around an ISFS or ARB site within an 80-km (50-mi) radius is assumed to be 1,700,000 in the year 1977, distributed as shown in Figures A-1 and A-2 of Appendix A. The nearest dwelling is assumed to be a farmhouse adjacent to the site boundary southeast of the ISFS or ARB facility where the maximum ground-level concentration exists for atmospheric releases of radioactive materials. The eastern U.S. population in the year 1977 (assumed to be 80% of total U.S. population) is 174 million, and the world population is 4.1 billion, of which 80% is assumed to reside in the northern hemisphere. Assumptions of population growth rates are discussed in Reference 3.

B.2.2.1.2 Release of Radioactive Material

Release of radioactive materials to the environment during normal operation of an ISFS or ARB facility is assumed to be only through atmospheric pathways. Liquid pathways for radioactive materials are insignificant because of collection and disposal methods. Some liquid wastes are generated during decontamination, etc., but they are recycled. Other liquid wastes, such as evaporator bottoms, are treated and packaged for storage (Section B.2.2.6). All radioactive solid wastes are packaged for storage (Section B.2.2.6).

There is only one source of radioactive material at a storage facility, the spent fuel, whether in shipping casks or in storage basins. Radioactive material released consists of fission products, actinides, and activation products. These radionuclides may come from crud deposited on the fuel cladding during reactor service or may result from leakage of spent fuel through defects in the cladding. Release of radionuclides at the facility results from 1) the release of radionuclides to the cask cavity during transport of the fuel and 2) the release of radionuclides to the basin water during subsequent handling and storage of the spent fuel. Releases caused by transportation occur at the storage facility when the cask is vented through the off-gas system. Releases resulting from handling and storage are through two other pathways to the atmosphere, the ventilating air and the evaporator overheads. In this report, all releases that might occur through the evaporator overheads are included in the releases via the ventilating air.

B.2.2.1.2.1 Fuel Failure Rates

Transportation - Cladding failures may occur during transportaton of the spent fuel to the ISFS or ARB facilities. These failures may be due to mechanical or physical damage to the cladding from vibrations, shock, and other stress encountered by the fuel casks on highways and railroads or during rail car coupling operations. If spent fuel elements fail during normal transportation, the casks will contain any gases or particulates released to the cavity of the cask. At the storage facility, all of the fission gas and part of the particulates will be vented to the facility off-gas system for treatment. For this assessment, 0.01% of the fuel elements are assumed to fail during normal transport as discussed in Appendix C and in Reference 3.

Handling and Storage - Storage of irradiated nuclear fuel in water basins has been standard practice since nuclear reactors first began operation about 34 years ago. Spent power reactor fuel has been stored in water basins for almost 20 years, since the first power reactor began discharging fuel. During this time, the fuel has been safely and successfully stored without any significant detriment to the surrounding environment or population. This storage has also been accomplished without any serious deterioration of the quality of the fuel cladding.[10]

At the Receiving Basin for Offsite Fuel (RBOF) at the Savannah River Plant, spent reactor fuel assemblies have been stored for more than 12 years. In that time, no failures attributed to basin storage have been reported. Sixteen assemblies or elements have been dropped or otherwise involved in a handling accident at RBOF, which corresponds to a frequency of approximately one drop per 1000 fuel assemblies handled. None of these dropped fuel assemblies released any radionuclides. Based upon a recent survey[10] of utility handling of spent fuel, nine fuel assemblies out of several thousand were dropped during handling. Of these nine dropped assemblies, only two cases of possible cladding failure were detected. In both of these cases, the release of radionuclides was momentary. If this momentary release of radionuclides from the fuel is classified as fuel cladding failure, a rupture rate of 0.2 per fuel drop can be predicted. Combining the frequency of dropping the fuel with that of cladding failure, the frequency of dropping and rupturing one or more fuel rods in an assembly can be estimated to be 2×10^{-4}. In an effort to conservatively estimate the consequences of fuel failure in this EIS, a failure rate of 2×10^{-3} is assumed for fuel handling.

Reactor experience has shown that current reactor fuel fails at a rate[11] of one failure per 10,000 fuel elements irradiated per year. Because there has been no experience with fuel failure during storage in water basins, even though reactor operation is much more severe than water basin storage conditions, it is assumed in this volume that fuel fails at a rate of one failure per 10,000 fuel elements stored per year. Since most spent fuel will probably be stored on the average less than ten years, it is assumed in this volume that one out of 1000 fuel elements fail during storage. To add additional conservatism to the analysis, fuel failure consequences are calculated based upon the radionuclide content of the spent fuel as it is received in the ISFS facility.

B.2.2.1.2.2 Fractional Release

Off-Gas System - Release of radioactive material through the off-gas system other than from the processing of shipping casks containing leaking fuel elements is assumed to be negligible. In the process of unloading the cask at the storage facility, the cask is vented to the off-gas system. Treatment is provided in the off-gas system to remove iodine. The decontamination factor (DF) for iodine removal is 10^3. The DF for particulate removal (prefilter and one stage of HEPA) is 10^4. The release fractions from fuel to environment through the cask and off-gas system are shown in Table B-4.

TABLE B-4

Atmospheric Release Fractions from Off-Gas Systems at Storage Basin Facilities Receiving Spent Fuel

Nuclide	*Fraction of Fuel Leaking*	*Fraction of Activity Released to Cask Cavity*	*Fraction to Off-Gas System*	*Fraction to Atmosphere*	*Overall Release Fraction to Atmosphere*
^{3}H	1×10^{-4}	1×10^{-2}	1	1	1×10^{-6}
^{14}C	1×10^{-4}	3×10^{-2}	1	1	3×10^{-6}
^{85}Kr	1×10^{-4}	3×10^{-1}	1	1	3×10^{-5}
^{129}I	1×10^{-4}	1×10^{-1}	1	1×10^{-3} [a]	1×10^{-8}
Particulates[b]	1×10^{-4}	1×10^{-4}	0.1	1×10^{-4} [c]	1×10^{-13}

a. Charcoal filters in off-gas system.

b. Assumed to be other fission products and actinides.

c. Air passed through a prefilter and a HEPA filter.

Ventilating Air — Radioactive material enters the ventilating air either as fission gas from assemblies that undergo cladding failure at the storage basin or as particulate material released from the surface of storage basins and handling pools.

Only that fraction of the radionuclides from the fuel matrix that is in the core-clad gap and plenum regions of the fuel elements during reactor operation is assumed to be available for escape from the spent fuel in the event of failure of the cladding during routine operation. Assumptions on the core-clad gap and plenum space activity and release are summarized in Table B-5.

All of the ^{85}Kr, ^{14}C, and tritium released from the fuel element is assumed to be released from the surface of the basin water to the building ventilation system. Basin water is assumed to retain 99% of the radioiodine, and only 1% is released to the ventilation system.

Overall release fractions of these gaseous radionuclides from the storage facility are shown in Table B-6. This table shows the release fractions assumed from both spent fuel handling and storage.

As shown in Table B-6, essentially all particulate fission products are assumed to be retained by the basin water and eventually removed by the filter deionizer system. However, some particulate fission products are released to the environment from the surface of the basin water. The normal radioactivity content of the basin water at the storage facility will be maintained at $\leq 2 \times 10^{-4}$ Ci/m^3 by a water treatment system. (See Reference 3 for additional details on the water treatment system assumed in the generic ISFS or ARB basin facility.) Based upon operating experience at RBOF at the Savannah River Plant, it is expected that a storage facility will release no more than 1.7×10^{-2} Ci/year of radionuclides as particulate material for each 500 MTU storage pool in service. This activity is expected to be distributed as follows: ^{55}Fe = 4%, ^{60}Co = 5%, ^{90}Sr = 1%, ^{134}Cs = 12%, ^{137}Cs = 78%.

B.2.2.1.2.3 Releases

The release of radionuclides to the atmosphere at the ISFS or ARB facility as a result of transportation and handling is determined from the release fractions, the annual schedule of receipts, storage or shipment of spent fuel, the assumed age of the spent fuel, and the radionuclide distribution (from Reference 3).

TABLE B-5

Radionuclides Available for Release - Handling and Storage

Radionuclide[a]	*Fraction of Nuclide Activity in Void Space in Spent Fuel Assemblies*	*Fraction of Nuclide Activity Released from Spent Fuel to Basin Water*
^{3}H	0.01	0.01
^{14}C	0.03	0.03
^{85}Kr	0.3	0.3
^{129}I	0.1	0.1
Other Fission products	0.0001	0.0001
Actinides	essentially none	negligible

a. ^{85}Kr and ^{129}I data are taken from Reference 12.

TABLE B-6

Atmospheric Release Fraction from Storage Basins

Nuclide	*Fraction of Fuel Leaking*	*Fraction of Nuclide Activity Released to Water Basin*	*Fraction Released to Room Air*	*Fraction to Atmosphere*	*Overall Atmospheric Release Fraction*
Spent Fuel Handling[a]					
^{3}H	0.002	0.01	1	1	2×10^{-5}
^{14}C	0.002	0.03	1	1	6×10^{-5}
^{85}Kr	0.002	0.3	1	1	6×10^{-4}
^{129}I	0.002	0.1	0.01	1	2×10^{-6}
Other Fission Products	0.002	0.0001	Negligible	Negligible	Negligible
Actinide	0.002	0.0001	Negligible	Negligible	Negligible
Spent Fuel Storage					
^{3}H	0.001	0.01	1	1	1×10^{-5}
^{14}C	0.001	0.03	1	1	3×10^{-5}
^{85}Kr	0.001	0.3	1	1	3×10^{-4}
^{129}I	0.001	0.1	0.01	1	1×10^{-6}
Other Fission Products	0.001	0.0001	Negligible	Negligible	Negligible
Actinide	0.001	0.0001	Negligible	Negligible	Negligible

a. Failure is assumed to occur during transfer of fuel from the shipping cask to storage or during transfer of fuel from storage to a shipping cask.

A summary of the releases associated with handling and storage is given in Table B-7 for the total period of operation and Table B-8 for the maximum year's release. A summary of the releases at the storage facility associated with transportation is given in Table B-9 for the total period of operation.

B.2.2.1.3 Dose Commitment

B.2.2.1.3.1 Methodology

Radiation dose commitments from atmospheric releases of radionuclides from a storage basin are calculated for the following pathways: air submersion, inhalation, transpiration and drinking water (tritium oxide only), contaminated ground surface, and contamination of agricultural products.

TABLE B-7

Radionuclides Released to Atmosphere During Normal Storage Basin Operation, Cumulative Curies Released

Nuclide	*Centralized Storage (Alternative 1A) or Decentralized Storage With Full-Core Reserve (Alternative 1B-1) - Policy Implemented*		*Decentralized Storage With Discharge Capabilities - Policy Implemented (Alternative 1B-2) or Polivy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
	Disposition Facility Startup		*Disposition Facility Startup*		*Disposition Facility Startup*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*
^{3}H	9.7×10^{1}	8.1×10^{2}	8.8×10^{0}	3.7×10^{2}	9.8×10^{-1}	8.1×10^{2}
^{14}C	5.3×10^{-1}	6.1×10^{0}	4.6×10^{-2}	2.4×10^{0}	5.4×10^{-1}	5.2×10^{0}
^{85}Kr	6.2×10^{4}	5.1×10^{5}	5.4×10^{3}	2.4×10^{5}	6.3×10^{4}	5.1×10^{5}
^{129}I	1.0×10^{-3}	9.6×10^{-3}	8.5×10^{-5}	4.4×10^{-3}	1.0×10^{-3}	9.7×10^{-3}
^{55}Fe	6.9×10^{-2}	1.1×10^{0}	5.6×10^{-3}	5.8×10^{-1}	2.4×10^{-1}	1.6×10^{0}
^{60}Co	9.0×10^{-2}	1.3×10^{0}	7.0×10^{-3}	7.2×10^{-1}	3.0×10^{-1}	2.0×10^{0}
^{90}Sr	1.8×10^{-2}	2.7×10^{-1}	1.4×10^{-3}	1.5×10^{-1}	6.0×10^{-2}	9.0×10^{-1}
^{134}Cs	2.1×10^{-1}	3.2×10^{0}	1.7×10^{-2}	1.7×10^{0}	7.2×10^{-1}	4.8×10^{0}
^{137}Cs	1.4×10^{0}	2.1×10^{1}	1.1×10^{-1}	1.1×10^{1}	4.7×10^{0}	3.1×10^{1}

TABLE B-8

Radionuclides Released to Atmosphere During Normal Storage Basin Operation, Curies, Maximum Year

Disposition Facility Startup →	*Centralized Storage (Alternative 1A) or Decentralized Storage With Full-Core Reserve (Alternative 1B-1) - Policy Implemented*		*Decentralized Storage With Discharge Capabilities - Policy Implemented (Alternative 1B-2) of Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*
Nuclide						
^{3}H	2.0×10^{1}	6.6×10^{1}	3.2×10^{0}	3.8×10^{1}	1.2×10^{1}	1.8×10^{1}
^{14}C	9.5×10^{-2}	3.2×10^{-1}	1.6×10^{-2}	1.8×10^{1}	5.9×10^{-2}	8.9×10^{-2}
^{85}Kr	1.3×10^{4}	1.2×10^{4}	2.1×10^{3}	2.4×10^{4}	7.9×10^{3}	1.2×10^{4}
^{129}I	1.8×10^{-4}	6.0×10^{-4}	2.9×10^{-5}	3.4×10^{-4}	1.1×10^{-4}	1.7×10^{-4}
^{55}Fe	8.0×10^{-3}	3.8×10^{-2}	8.0×10^{-4}	2.0×10^{-2}	1.4×10^{-3}	1.9×10^{-3}
^{60}Co	1.0×10^{-2}	4.8×10^{-2}	1.0×10^{-3}	2.5×10^{-2}	1.7×10^{-3}	2.4×10^{-3}
^{90}Sr	2.0×10^{-3}	9.6×10^{-3}	2.0×10^{-4}	5.0×10^{-3}	3.4×10^{-4}	4.8×10^{-4}
^{134}Cs	2.4×10^{-2}	1.2×10^{-1}	2.4×10^{-3}	6.0×10^{-2}	4.1×10^{-3}	5.8×10^{-3}
^{137}Cs	1.6×10^{-1}	7.5×10^{-1}	1.6×10^{-2}	3.9×10^{-1}	2.7×10^{-2}	3.7×10^{-2}

TABLE B-9

Radionuclides Released to Atmosphere During Cask Venting at Storage Basin Facilities

Amount of Radioactivity Released, Total Campaign, curies

Nuclide	*Centralized Storage (Alternative 1A) or Decentralized Storage With Full-Core Reserve (Alternative 1B-1) - Policy Implemented* — *Disposition Facility Startup* 1985	1995	*Decentralized Storage With Discharge Capabilities - Policy Implemented (Alternative 1B-2) of Policy Not Implemented (Alternative 2A)* — *Disposition Facility Startup* 1985	1995	*Decentralized Storage in At-Reactor Basins Policy Not Implemented (Alternate 2B)* — *Disposition Facility Startup* 1985	1995
^{3}H	2.2×10^{0}	2.1×10^{1}	1.9×10^{-1}	9.8×10^{0}	2.2×10^{0}	2.2×10^{1}
^{14}C	1.1×10^{-2}	1.0×10^{-1}	9.2×10^{-4}	4.7×10^{-2}	1.1×10^{-2}	1.0×10^{-1}
^{85}Kr	1.4×10^{3}	1.4×10^{4}	1.2×10^{2}	6.3×10^{3}	1.4×10^{3}	1.4×10^{4}
^{90}Sr	3.8×10^{-5}	3.7×10^{-4}	3.3×10^{-6}	1.7×10^{-4}	7.7×10^{-6}	2.7×10^{-5}
^{129}I	2.0×10^{-6}	1.9×10^{-5}	1.7×10^{-7}	8.8×10^{-6}	2.0×10^{-6}	1.9×10^{-5}
^{134}Cs	3.4×10^{-5}	3.2×10^{-4}	2.9×10^{-6}	1.5×10^{-4}	6.8×10^{-6}	2.4×10^{-5}
^{137}Cs	5.0×10^{-5}	5.1×10^{-4}	4.5×10^{-6}	2.4×10^{-4}	1.1×10^{-5}	3.7×10^{-5}
^{144}Ce	1.7×10^{-5}	1.6×10^{-4}	1.5×10^{-6}	7.7×10^{-5}	3.5×10^{-6}	1.2×10^{-5}
^{147}Pm	2.1×10^{-5}	2.1×10^{-4}	1.8×10^{-6}	9.3×10^{-5}	4.2×10^{-6}	1.5×10^{-5}
^{154}Eu	2.7×10^{-6}	2.6×10^{-5}	2.3×10^{-7}	1.2×10^{-5}	5.4×10^{-7}	1.9×10^{-6}
^{237}Np	1.8×10^{-10}	1.8×10^{-9}	1.6×10^{-11}	8.1×10^{-10}	3.7×10^{-11}	1.3×10^{-10}
^{238}Pu	1.5×10^{-6}	1.4×10^{-5}	1.3×10^{-7}	6.8×10^{-6}	3.0×10^{-7}	1.0×10^{-6}
^{239}Pu	1.7×10^{-7}	1.6×10^{-6}	1.5×10^{-7}	7.7×10^{-7}	3.5×10^{-8}	1.2×10^{-7}
^{240}Pu	2.5×10^{-7}	2.4×10^{-6}	2.2×10^{-8}	1.1×10^{-6}	5.1×10^{-8}	1.8×10^{-7}
^{241}Pu	4.6×10^{-5}	4.3×10^{-4}	3.9×10^{-6}	2.1×10^{-4}	9.2×10^{-6}	3.2×10^{-5}
^{242}Pu	7.0×10^{-10}	6.7×10^{-9}	6.0×10^{-11}	3.2×10^{-9}	1.4×10^{-10}	4.9×10^{-10}
^{241}Am	3.7×10^{-7}	3.5×10^{-6}	3.0×10^{-8}	1.7×10^{-6}	7.4×10^{-8}	2.5×10^{-7}
^{242}Cm	3.9×10^{-8}	3.7×10^{-7}	3.3×10^{-9}	1.8×10^{-7}	3.9×10^{-8}	3.8×10^{-7}
^{243}Cm	1.7×10^{-9}	1.6×10^{-8}	1.5×10^{-10}	7.7×10^{-9}	3.5×10^{-10}	1.2×10^{-9}
^{244}Cm	1.0×10^{-6}	9.8×10^{-6}	8.7×10^{-8}	4.5×10^{-6}	2.1×10^{-7}	7.1×10^{-7}
^{245}Cm	1.7×10^{-10}	1.6×10^{-9}	1.4×10^{-7}	7.5×10^{-10}	3.4×10^{-11}	1.2×10^{-10}

As used in this report, the term "dose commitment" consists of two parts: the internal dose commitment and the environmental dose commitment. The internal dose commitment is associated with an intake of a radionuclide and is defined as the total radiation dose to a reference organ resulting from that intake which will accrue during the remaining lifetime of the individual.[13] This includes the contribution of any radioactive daughters which are formed in the body as the parent radionuclide decays. The exposed individual is assumed to be an adult, 20 years of age at the time of intake, who will live to age 70. Thus, the internal dose commitment is a 50-year dose commitment. Environmental dose commitment is from worldwide recycling of radionuclides (^{3}H, ^{14}C, ^{85}Kr) and from nuclides such as ^{129}I and particulate fission and activation products persistent in the local environment for significant time periods following release. Environmental dose commitment is calculated for the period of release and for a 100-year period after to provide an assessment of effects of persistent nuclides.

7-h The long-term potential consequences for very long-lived radionuclides are not included beyond 100 years. The difficulty in extrapolating the impact out to the time of complete radioactive decay lies in developing rational models which will account for the availability of the radionuclide in question, when it is generally agreed that environmental depletion occurs through environmental sinks, such as movement to the deep ocean, or migration downward in soil beyond the accessibility of rooted plants. Further complications are introduced by attempting projections of populations over eons of time approaching geological ages. Even 100-year projections suffer to some extent from these uncertainties.

Maximum Individual — Dose commitment is calculated for the hypothetical individual who is assumed to reside continuously at the site boundary at the point of highest atmospheric concentrations. Table B-10 shows the dose commitment to this individual during the year of maximum release of radionuclides from the storage basins and, also, the cumulative dose for the entire period of operation of the basins if the policy is implemented with centralized storage. Table B-10 also shows the dose commitments for the same individual with decentralized storage or if the policy is not implemented. For comparison, individual exposure to natural radiation sources in the United States ranges from 100 mrem/yr to 250 mrem/yr, averaging 130 mrem/yr. World exposure to natural radiation sources averages 100 mrem/yr.[4]

TABLE B-10

Radiation Dose Commitment[a] to Hypothetical Individual Receiving the Maximum Dose from Basin Releases, mrem

Disposition Facility Startup, 1985

	^3H	^{14}C	^{85}Kr	^{129}I	*Exposure to Contaminated Ground*[b]	*Inhalation*[b]	*Foodstuff*[b]	*Total*
Centralized Storage (Alternative 1A) and Decentralized Storage with Full-Core Reserve (1B-1) - Policy Implemented								
Maximum Release, Yearly								
Whole Body	0.0035	0.0019	0.003	-	2.6[c]	0.0008	0.15	2.8
Thyroid[d]	-	-	-	0.017		-	-	0.017
Bone[d]	-	-	-	-		0.0038	0.012	0.016
Red Marrow (leukemia)[d]	-	0.0033	-	-	-	-	-	0.0033
Lungs[d]	-	-	0.0062	-	-	-	-	0.0062
ISFS Basin Operation, Cumulative Release								
Whole Body	0.017	0.011	0.0077	-	22[e]	0.007	1.4	23
Thyroid	-	-	-	0.092	-	-	-	0.92
Bone[a]	-	-	-	-	-	0.035	3.3	3.3
Red Marrow (leukemia)[d]	-	0.019	-	-	-	-	-	0.019
Lungs	-	-	0.016	-	-	-	-	0.016
Decentralized Storage with Discharge Capabilities - Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)								
Maximum Release, Yearly								
Whole Body	0.0004	0.0003	0.0005	-	0.26	0.0001	0.016	0.28
Thyroid[d]	-	-	-	0.0027	-	-	-	0.0027
Bone[d]	-	-	-	-	-	0.0004	0.037	0.037
Red Marrow (leukemia)[d]	-	0.0006	-	-	-	-	-	0.0006
Lungs[d]	-	-	0.001	-	-	-	-	0.001
ISFS Basin Operation, Cumulative Release								
Whole Body	0.0011	0.0009	0.0013	-	1.8[e]	0.0005	0.11	1.9
Thyroid[d]	-	-	-	0.0079	-	-	-	0.0079
Bone[d]	-	-	-	-	-	0.0027	0.26	0.26
Red Marrow (leukemia)[d]	-	0.0016	-	-	-	-	-	0.0016
Lungs	-	-	0.0027	-	-	-	-	0.0027
Decentralized Storage in At-Reactor Basins - Policy Not Implemented (Alternative 2B)								
Maximum Release, Yearly								
Whole Body	0.0015	0.0012	0.0018	-	0.44[c]	0.0001	0.026	0.47
Thyroid[d]	-	-	-	0.01	-	-	-	0.01
Bone[d]	-	-	-	-	-	0.0006	0.06	0.06
Red Marrow (leukemia)[d]	-	0.0021	-	-	-	-	-	0.0021
Lungs[d]	-	-	0.0037	-	-	-	-	0.0037
ARB Operation, Cumulative Release								
Whole Body	0.014	0.011	0.016	-	4.0[e]	0.0012	0.23	4.3
Thyroid	-	-	-	0.09	-	-	-	0.09
Bone[d]	-	-	-	-	-	0.0058	0.54	0.55
Red Marrow (leukemia)[d]	-	0.019	-	-	-	-	-	0.019
Lungs[d]	-	-	0.033	-	-	-	-	0.033

Disposition Facility Startup, 1995

	^3H	^{14}C	^{85}Kr	^{129}I	*Exposure to Contaminated Ground*[b]	*Inhalation*[b]	*Foodstuff*[b]	*Total*
Centralized Storage (Alternative 1A) and Decentralized Storage with Full-Core Reserve (1B-1) - Policy Implemented								
Maximum Release, Yearly								
Whole Body	0.0027	0.0021	0.0033	-	4.3	0.0013	0.29	4.6
Thyroid[d]	-	-	-	0.018	-	-	-	0.018
Bone[d]	-	-	-	-	-	0.0063	0.57	0.58
Red Marrow (leukemia)[d]	-	0.0037	-	-	-	-	-	0.0037
Lungs[d]	-	-	0.0006	-	-	-	-	0.0006
ISFS Basin Operation, Cumulative Release								
Whole Body	0.033	0.04	0.012	-	100[e]	0.038	7	110
Thyroid	-	-	-	0.29	-	-	-	0.29
Bone[a]	-	-	-	-	-	0.18	16	16
Red Marrow (leukemia)[d]	-	0.07	-	-	-	-	-	0.07
Lungs	-	-	0.026	-	-	-	-	0.026
Decentralized Storage with Discharge Capabilities - Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)								
Maximum Release, Yearly								
Whole Body	0.0012	0.0009	0.0014	-	1.6[c]	0.0005	0.093	1.7
Thyroid[d]	-	-	-	0.008	-	-	-	0.008
Bone[d]	-	-	-	-	-	0.024	0.24	0.26
Red Marrow (leukemia)[d]	-	0.0016	-	-	-	-	-	0.0016
Lungs[d]	-	-	0.003	-	-	-	-	0.003
ISFS Basin Operation, Cumulative Release								
Whole Body	0.012	0.012	0.014	-	43[e]	0.014	2.8	46
Thyroid[d]	-	-	-	0.10	-	-	-	0.10
Bone[d]	-	-	-	-	-	0.068	6.8	6.9
Red Marrow (leukemia)[d]	-	0.020	-	-	-	-	-	0.020
Lungs	-	-	0.028	-	-	-	-	0.028
Decentralized Storage in At-Reactor Basins - Policy Not Implemented (Alternative 2B)								
Maximum Release, Yearly								
Whole Body	0.0021	0.0017	0.0026	-	0.65	0.0002	0.035	0.69
Thyroid[d]	-	-	-	0.015	-	-	-	0.015
Bone[d]	-	-	-	-	-	0.0009	0.087	0.088
Red Marrow (leukemia)[d]	-	0.0029	-	-	-	-	-	0.0029
Lungs[d]	-	-	0.0054	-	-	-	-	0.0054
ARB Operation, Cumulative Release								
Whole Body	0.032	0.025	0.039	-	9.8	0.0028	0.51	10.4
Thyroid	-	-	-	0.22	-	-	-	0.22
Bone[d]	-	-	-	-	-	0.014	1.3	1.3
Red Marrow (leukemia)[d]	-	0.043	-	-	-	-	-	0.043
Lungs[d]	-	-	0.081	-	-	-	-	0.081

a. 50-year dose commitment.

b. Due to nuclides other than ^3H, ^{14}C, ^{85}Kr, and ^{129}I.

c. Dose from maximum year of releases from releases during that year.

d. Doses in addition to organ dose from whole body irradiation.

e. Cumulative dose during the study period.

B.2.2.1.3.2 Local, United States, and World Population

Population dose commitments are calculated for the local [80 km (50 mi)], United States, and world populations. The ^{3}H, ^{14}C, and ^{85}Kr eventually spread from the local area to the surrounding U.S. and then throughout the world, but ^{129}I and radioactive particulates are assumed to be deposited only on U.S. soil. For purposes of calculating dose commitment, the generic ISFS and ARB facilities are assumed to be located in the midwest; therefore, only the population of the eastern U.S. is exposed on the
C first pass before worldwide dispersion. This assumption maximizes environmental effects; if an eastern location were assumed, this dose from the first pass would be lower. In calculating the worldwide 100-year doses, the population growth is extrapolated to 37 x 10^{9} people (nine times the present population) by the year 2095. The world food supplies may not support that population level; thus, the calculated population dose commitment is probably higher than that which will result from these releases and is, therefore, conservative. Table B-11 gives the local, U.S., and worldwide dose commitment from operation of the storage facility and includes the dose from persistent effects for a 100-year period after operation.

B.2.2.1.4 Health Effects from Low Levels of Ionizing Radiation

7-f The potential health effects on human populations of low levels of ionizing radiation are discussed in this section. The health effects considered are long-delayed somatic and genetic effects. In this environmental impact statement, the somatic effects considered are malignancies resulting from irradiation of the whole body, lung, bone, bone marrow, and the thyroid; genetic effects are those which occur in future generations because of exposure of the gonads.

7-g Recently, much literature has dealt with the prediction of health effects from low levels of ionizing radiation. The most broadly accepted reports on these effects are the BEIR Report (1972)[14] by the National Academy of Sciences and the UNSCEAR Report (1977)[15] by the United Nations Scientific Committee on the Effects of Atomic Radiation. The National Academy of Sciences is currently preparing to release an update of the BEIR Report.[16]

This environmental statement adopts the linear dose-health effect relationships derived from the BEIR Report[14] by the
7-c Environmental Protection Agency (EPA).[17,18] No threshold dose is assumed for health effects. These dose-effect estimates are quite uncertain and may or may not overestimate the actual effects. The following is a quote from the EPA analysis of the fuel cycle:[17]

TABLE B-11

Population Dose Commitment from Storage Basin Releases, man-rem[a,b]

Critical Organ	Nuclide or Pathway	Disposition Facility Startup, 198[illegible]				Disposition Facility Startup, [illegible]			
		Local, 80-km Radius	*U.S., Less Local*	*World, Less U.S.*	*Total*	*Local, 80-km Radius*	*U.S., Less Local*	*World, Less U.S.*	*Total*
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) - Policy Implemented									
Whole Body	^{3}H	<1	<1	<1	<1	2	2	1	5
	^{14}C	<1	1	30	31	3	10	441	454
	^{85}Kr	<1	1	25	26	3	9	278	290
	Exposure to Contaminated Ground	519	415	-	934	8152	6713	-	14865
	Inhalation[c]	<1	<1	-	<1	2	2	-	4
	Foodstuff[c]	28	22	-	50	436	350	-	786
	Total	547(547)	439(438)	55(31)	1041(1016)	8598(8595)	7086(7078)	720(379)	16404(16052)
Thyroid[d]	^{129}I	4	4	-	8	44	37	-	81
Bone[d]	Inhalation	1	1	-	2	10	10	-	20
	Foodstuff	67	53	-	120	1007	815	-	1822
	Total	68	54	-	122	1017	825	-	1842
Lung[d]	^{85}Kr	<1	1	19	20	6	12	373	391
Red Marrow[d]	^{14}C	<1	2	52	54	5	17	763	785
Decentralized Storage with Discharge Capabilities - Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)									
Whole Body	^{3}H	<1	<1	<1	<1	1	1	<1	2
	^{14}C	<1	<1	3	3	1	4	193	198
	^{85}Kr	<1	<1	2	2	1	4	111	116
	Exposure to Contaminated Ground	40	32	-	72	4491	3743	-	8234
	Inhalation[c]	<1	<1	-	<1	2	1	-	3
	Foodstuff[c]	2	2	-	4	242	192	-	434
	Total	42(42)	34(34)	5(2)	81(76)	4738(4737)	3945(3942)	304(157)	8987(8836)
Thyroid[d]	^{129}I	<1	<1	-	<1	20	17	-	37
Bone[c]	Inhalation	<1	<1	-	<1	5	5	-	10
	Foodstuff	6	4	-	10	599	474	-	1073
	Total	6	4	-	10	604	479	-	1083
Lung[d]	^{85}Kr	<1	<1	4	4	2	8	229	239
Red Marrow[d]	^{14}C	<1	<1	5	5	2	7	334	343
Decentralized Storage in At-Reactor Basins – Policy Not Implemented (Alternative 2B)									
Whole Body	^{3}H	<1	<1	<1	<1	2	2	1	5
	^{14}C	<1	1	32	33	2	8	403	413
	^{85}Kr	<1	<1	32	32	3	9	341	353
	Exposure to Contaminated Ground	1677	1336	-	3013	10900	8690	-	19590
	Inhalation[c]	1	<1	-	1	3	2	-	5
	Foodstuff[c]	93	74	-	167	606	483	-	1089
	Total	1771(1771)	1411(1410)	64(36)	3246(3217)	11516(11514)	9194(9187)	745(410)	21455(21111)
Thyroid[d]	^{129}I	4	4	-	8	42	36	-	78
Bone[c]	Inhalation	2	2	-	4	15	12	-	27
	Foodstuff	222	177	-	399	1430	1140	-	2570
	Total	224	179	-	403	1445	1152	-	2597
Lung[d]	^{85}Kr	<1	<1	66	66	6	19	706	731
Red Marrow[d] (Leukemia)	^{14}C	<1	2	55	57	3	14	697	714

a. Continued effects of releases are included for a 100-year period after end of ISFS or At-Reactor Basin storage.

b. Where gonad doses differ from whole body doses, gonad doses are shown in parentheses.

c. Includes contribution from nuclides other than ^{3}H, ^{14}C, ^{85}Kr, and ^{129}I.

d. Doses in addition to organ dose from whole body irradiation.

The numerical risk estimates used are primarily from the BEIR Report.[14] What must be emphasized is that though these numbers may be used as the best available for the purpose of risk-cost benefit analyses, they cannot be used to accurately predict the number of casualties. For a given dose equivalent, the BEIR Report estimates a range for the health impact per million exposed persons. For example, the BEIR results from a study of the major sources of cancer mortality data yield an absolute risk* estimate of 54 to 123 deaths annually per 10^6 persons per rem for a 27-year followup period. Depending upon the details of the risk model used, the BEIR Committee's relative risk** estimate is 160 to 450 deaths per 10^6 persons per rem. It is seen that the precision of these estimates is at best about a factor of 3 to 4, even when applied to sample populations studied on the basis of the same dose rates. The application of the BEIR risk estimates to exposures at lower dose rates and to population groups more heterogeneous than those studied increases the uncertainty in the risk estimates. Considering the limitations of presently available data and the lack of an accepted theory of radiocarcinogenesis, emphasis should be placed on the difference in risk estimates between the various procedures and countermeasures discussed in this report rather than on the absolute numbers. Where the absolute numbers must be used for risk-cost-benefit balancing, it should be revised as new information becomes available. Notwithstanding these disclaimers, it is also pertinent to note that we are in a better position to evaluate the true risks and the accompanying uncertainties from low levels of radiation than from low concentrations of other environmental pollutants which might affect populations....[17]

The position of the National Council on Radiation Protection[19] is

The linear dose-effect hypothesis has been coming into frequent use in analyses in which population exposures are expressed in the form of person-rem, including doses of 1 mrem/yr or less to population groups and doses to individual organs, with linear extrapolation to damage estimates through the use of the BEIR Report values. The indications of a significant dose rate influence on radiation effects

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* Absolute risk estimates are based upon the reported number of cancer deaths per rad that have been observed in exposed population groups, e.g., Hiroshima, Nagasaki, etc.

** Relative risk estimates are based upon the percentage increase of ambient cancer mortality per rem.

would make completely inappropriate the current practice of summing of doses at all levels of dose and dose rate in the form of total person-rem for purposes of calculating risks to the population on the basis of extrapolation of risk estimates derived from data at high doses and dose rates.

The NCRP wishes to caution governmental policy-making agencies of the unreasonableness of interpreting or assuming 'upper limit' estimates of carcinogenic risks at a low radiation level, derived from linear extrapolation from data obtained at high doses and dose rates as actual risks, and of basing unduly restrictive policies on such an interpretation or assumption. The NCRP has always endeavored to ensure public awareness of the hazards of ionizing radiation, but it has equally determined to ensure that such hazards are not greatly overestimated. Undue concern, as well as carelessness with regard to radiation hazards, is considered detrimental to the public interest.[19]

7-c The dose-effect relationship factors derived by the EPA are neither upper nor lower estimates of probability but are computed on the same basis as the probability characterized as "the most likely estimate" in the BEIR Report; that is, they are averages of the relative and absolute risk models considered in the BEIR
7-f Report. The EPA dose-effect factors are shown in Table B-12. This table includes both somatic and genetic effects. For somatic effects, two columns are shown, i.e., for total malignancies (both fatal and nonfatal) and fatal malignancies, only. The somatic dose-effect factors used in this environmental statement make no distinction between lethal and sublethal cancers and use the factors shown in the first column, the total potential incidence of malignancies. The genetic effects considered include congenital anomolies, constitutional and degenerative diseases, etc. Because of the seriousness of these genetic effects, e.g., mongolism, the emotional and financial stress would be similar to death impact. This environmental statement sums genetic and total cancer risk as total health effects.

7-d The most recent and most thorough estimates of cancer risks from radiation exposure are those contained in the 1977 UNSCEAR Report.[15] These estimates are listed in Table B-13 along with the BEIR Report[14] estimates. The UNSCEAR Report cautions that these values are "...derived essentially from mortalities induced at doses in excess of 100 rad. The value appropriate to the much lower dose levels involved in occupational exposure, and even more so in environmental exposures to radiation may well be substantially less..." Also shown in Table B-13 are risk estimates from the 1977 recommendation of the International Commission on Radiological Protection,[13] which are based primarily upon the UNSCEAR Report. The EPA dose-fatal cancer and genetic effect factors are included for comparison.

TABLE B-12

EPA Dose Effect Conversion Factors

	Total Somatic Health Effects per 10^6 man-rem, cancers	*Fatal Somatic Health Effects per 10^6 man-rem, cancers*	*% Mortality*	*Genetic Effects per 10^6 man-rem*
Whole Body[18]	400	200	50	
Lung[18]	40	40	100	
Bone[17]	32	16	50	
Red Marrow[17] (Leukemia)	54	54	100	
Thyroid[18]	60	12	20	
Gonads[18]				200

TABLE B-13

7-e

Comparison of Dose-Effect Conversion Factors

	Estimates of Effects per Million Man-Rem						
	BEIR[14]						
	Absolute Risk Model		Relative Risk Model				
Effect	*30-Year Plateau*	*Life Plateau*	*30-Year Plateau*	*Life Plateau*	*EPA*[17,18]	*UNSCEAR*[15]	*ICRP-26*[13]
Malignancies, fatal							
Red Marrow, leukemia	26[a]		37[a]		54	15-25	20
Lung	16	19			40	25-50	20
Bone	2.4	3.0	122 (Lung, Bone, Thyroid)	417 (Lung, Bone, Thyroid)	16	2-5	5
Thyroid	-	-			12	5-15	5
Whole Body, total	86	100	159	454	200	100	100
Genetic	-	-	60-1500		200	185	200

a. A 10-year risk plateau is used for in utero exposure. All other exposures use a 25-year risk plateau.

7-c Recently, there has been some controversy concerning the magnitudes of estimated risks from ionizing radiation. The Natural Resources Defense Council, in commenting on the draft version (August 1978) of this environmental statement, included an April 1978 report by Arthur R. Tamplin entitled Biological Effects of Radiation Underestimated.[20] In this report, Dr. Tamplin postulates that the upper estimate of somatic effects in the BEIR Report may be low by a factor of ten and genetic effect estimates may be low by a factor of eight. As can be seen from comparison of dose-effect factors in Table B-13, most of the estimates by others are of the same order of magnitude. The updated BEIR Report (1979)[16] was not available at the time of preparation of this environmental statement, but it is understood that the updated estimate of health effects does not differ greatly from the 1972 report. In view of this, the EPA dose-effect factors will be used in this statement as being representative of the estimates of most of the groups making estimates.

When the population doses given in Table B-11 and the factors in Table B-12 are combined, health effects (from ISFS facility operation) can be calculated for each alternative (Table B-14).

The calculated statistical incidences of fatal cancers resulting from ISFS or ARB facility operations (using EPA dose-effect factors) and the fatalities per 100,000 population are also given in Table B-14. These values are extremely low compared to the observed causes of death in Table B-15 for the United States in the year 1975 and would be impossible to identify as being specifically caused by storage basin operations even for the local 80-km (50-mi) radius population.

Genetic effects are estimated by using EPA gonad dose-effect factors (^{3}H, ^{14}C, and ^{85}Kr contribute significantly to the total dose). Table B-16 includes the genetic effect estimates and the frequency of these effects per 10^5 population each year. For comparison, about 200,000 babies are born in the United States each year with some type of mental or physical defect, a frequency of 67 cases per 10^5 population per year.

The dose-effect factor used to calculate genetic effects
7-g from occupational exposure was modified to better account for the male-female work force distribution expected to be used in radiation work and to account for a higher proportion of workers in the age of procreation than the BEIR Report[14] used for the general population. The genetic dose-effect factors used in this report for occupational exposure is 270 effects per million man-rem exposure to the work force.

TABLE B-14

Calculated Somatic Health Effects from Storage Basin Operations with EPA Dose-Effect Factors[a]

	Disposition Facility Startup, 1985					*Disposition Facility Startup, 1995*				
	Local	*U.S.*	*World*	*Total*	*Fatalities*	*Local*	*U.S.*	*World*	*Total*	*Fatalities*
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented										
Whole Body	2.2×10^{-1}	1.8×10^{-1}	2.2×10^{-2}	4.2×10^{-1}	2.1×10^{-1}	3.4×10^{0}	2.8×10^{0}	2.9×10^{0}	6.6×10^{0}	3.3×10^{0}
Thyroid[b]	2.4×10^{-4}	2.4×10^{-4}	-	4.8×10^{-4}	9.6×10^{-5}	2.6×10^{-3}	2.2×10^{-3}	-	4.9×10^{-3}	9.7×10^{-4}
Bone[b]	2.2×10^{-3}	1.7×10^{-3}	-	3.9×10^{-3}	2.0×10^{-3}	3.3×10^{-2}	2.6×10^{-2}	-	5.9×10^{-2}	2.9×10^{-2}
Lung[b]	$<4.0 \times 10^{-5}$	4.0×10^{-3}	7.6×10^{-4}	8.0×10^{-4}	8.0×10^{-4}	2.4×10^{-4}	4.8×10^{-4}	1.5×10^{-2}	1.6×10^{-2}	1.6×10^{-2}
Red Marrow (Leukemia)[b]	$<5.4 \times 10^{-5}$	1.1×10^{-4}	2.8×10^{-3}	2.9×10^{-3}	2.9×10^{-3}	2.7×10^{-4}	9.2×10^{-4}	4.1×10^{-2}	4.2×10^{-2}	4.2×10^{-2}
Total				4.3×10^{-1}	2.2×10^{-1}				6.7×10^{0}	3.4×10^{0}
Fatalities/10^{5} Population per year					1.2×10^{-8}					1.4×10^{-7}
Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)										
Whole Body	1.7×10^{-2}	1.4×10^{-2}	2.0×10^{-3}	3.2×10^{-2}	1.6×10^{-2}	1.9×10^{0}	1.6×10^{0}	1.2×10^{-1}	3.6×10^{0}	1.8×10^{0}
Thyroid[b]	$<6.0 \times 10^{-5}$	$<6.0 \times 10^{-5}$	-	$<6.0 \times 10^{-5}$	$<1.2 \times 10^{-5}$	1.2×10^{-3}	1.0×10^{-3}	-	2.2×10^{-3}	4.4×10^{-4}
Bone[b]	1.9×10^{-4}	1.3×10^{-4}	-	3.2×10^{-4}	1.6×10^{-4}	1.9×10^{-2}	1.5×10^{-2}	-	3.5×10^{-2}	1.7×10^{-2}
Lung[b]	$<4.0 \times 10^{-5}$	$<4.0 \times 10^{-5}$	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	8.0×10^{-5}	3.2×10^{-4}	9.2×10^{-3}	9.6×10^{-3}	9.6×10^{-3}
Red Marrow (Leukemia)[b]	$<5.4 \times 10^{-5}$	$<5.4 \times 10^{-5}$	2.7×10^{-4}	2.7×10^{-4}	2.7×10^{-4}	1.1×10^{-4}	3.8×10^{-4}	1.8×10^{-2}	1.9×10^{-2}	1.9×10^{-2}
Total				3.3×10^{-2}	1.7×10^{-2}				3.7×10^{0}	1.8×10^{0}
Fatalities/10^{5} Population per year					1.0×10^{-9}					7.1×10^{-8}
Decentralized Storage in At-Reactor Basins - Policy Not Implemented (Alternative 2B)										
Whole Body	7.1×10^{-1}	5.6×10^{-1}	2.6×10^{-2}	1.3×10^{0}	6.5×10^{-1}	4.6×10^{0}	3.7×10^{0}	3.0×10^{-1}	8.6×10^{0}	4.3×10^{0}
Thyroid[b]	2.4×10^{-4}	2.4×10^{-4}	-	4.8×10^{-4}	9.6×10^{-5}	2.5×10^{-3}	2.2×10^{-3}	-	4.7×10^{-3}	9.4×10^{-4}
Bone[b]	7.2×10^{-3}	5.7×10^{-3}	-	1.3×10^{-2}	6.4×10^{-3}	4.6×10^{-2}	3.7×10^{-2}	-	8.3×10^{-2}	4.2×10^{-2}
Lung[b]	$<4.0 \times 10^{-3}$	$<4.0 \times 10^{-5}$	2.6×10^{-3}	2.7×10^{-3}	2.7×10^{-3}	2.4×10^{-4}	7.6×10^{-4}	2.8×10^{-2}	2.9×10^{-2}	2.9×10^{-2}
Red Marrow (Leukemia)[b]	$<5.4 \times 10^{-5}$	1.1×10^{-4}	3.0×10^{-3}	3.1×10^{-3}	3.1×10^{-3}	1.6×10^{-4}	7.6×10^{-4}	3.8×10^{-2}	3.9×10^{-2}	3.9×10^{-2}
Total				1.3×10^{0}	6.6×10^{-1}				8.8×10^{0}	4.4×10^{0}
Fatalities/10^{5} Population per year					3.8×10^{-8}					1.9×10^{-7}

a. See text for discussion of dose effect factors used in the calculations and probable overestimation of health effects.

b. Organ health effects in addition to those included in whole body dose estimates.

TABLE B-15

Causes of Death in the United States[21,22]

Cause (1975)	*Deaths per Year per 10^5 Population*
Malignancies	174
Major cardiovascular diseases	459
Influenza and pneumonia	27
Bronchitis, emphysema, and asthma	12
Cirrhosis of liver	15
Suicide	13
Homicide	10
Accidents	48
Other causes	137
Total	895

Accidents (1975)	
Motor vehicle	22
Falls	7
Fires, burns	3
Drowning	4
Poisoning	3
Firearm	1
Aircraft	0.7
Electric current	0.5
Lightning	0.05
Bites and stings	0.02
Other	7
Total	48

TABLE B-16

Calculated Genetic Effects[a] from Storage Basin Operations

	Disposition Facility Startup, 1985				*Disposition Facility Startup, 1995*			
	Local	*U.S.*	*World*	*Total*	*Local*	*U.S.*	*World*	*Total*
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented								
Genetic Effects from ISFS Basin Operations	1.1×10^{-1}	8.8×10^{-2}	6.2×10^{-3}	2.0×10^{-1}	1.7×10^{0}	1.4×10^{0}	7.6×10^{2}	3.2×10^{0}
Genetic Effects from Background Radiation	5.2×10^{3}	6.8×10^{5}	3.6×10^{7}	3.6×10^{7}	5.8×10^{3}	7.8×10^{5}	4.8×10^{7}	4.8×10^{7}
Genetic Effects from ISFS Basin Operations per 10^5 Population				1.1×10^{-8}				1.3×10^{-7}
Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)								
Genetic Effects from ISFS Basin Operations	8.4×10^{-3}	6.8×10^{-3}	4.0×10^{-4}	1.5×10^{-2}	9.5×10^{-1}	7.9×10^{-1}	3.1×10^{-2}	1.8×10^{0}
Genetic Effects from Background Radiation	4.8×10^{3}	6.4×10^{5}	3.4×10^{7}	3.4×10^{7}	5.8×10^{3}	7.8×10^{5}	5.0×10^{7}	5.0×10^{7}
Genetic Effects from ISFS Basin Operations per 10^5 Population				9.2×10^{-10}				7.0×10^{-8}
Decentralized Storage in At-Reactor Basins - Policy Not Implemented (Alternative 2B)								
Genetic Effects from ARB Operations	3.5×10^{-1}	2.8×10^{-1}	7.2×10^{-3}	6.4×10^{-1}	2.3×10^{0}	1.8×10^{0}	8.2×10^{-2}	4.2×10^{0}
Genetic Effects from Background Radiation	4.7×10^{3}	6.1×10^{5}	3.3×10^{7}	3.4×10^{7}	3.4×10^{3}	4.6×10^{6}	4.6×10^{7}	4.6×10^{7}
Genetic Effects from ARB Operations per 10^5 Population				3.7×10^{-8}				1.8×10^{-7}

a. See text for discussion of genetic dose-effect factors.

B.2.2.1.5 Occupational Radiation Exposure and Accidental Deaths

Federal regulations[23] require that occupational external dose to an individual not exceed five rem/yr or a cumulated value of 5(N-18) rem, where N is the present age of the worker. Estimates of personnel exposure anticipated in nuclear facilities often assume an average personnel dose (not including administrative and other personnel who are not exposed to occupational radiation) of 40% of the maximum, or two rem/yr average for a five rem/yr limit.[24] It is anticipated that allowable personnel exposure will be reduced through regulatory incorporation of "as low as reasonably achievable" limits. Although such limits have not been determined for spent fuel storage facilities, for this volume the criterion of one rem/yr maximum exposure required of new DOE
7-b plutonium facilities[25] is assumed conservatively* to apply to storage basin operations. The average exposure of radiation workers is assumed to be 40% of the one rem limit, or 400 mrem/(year-person). Personnel exposure is assumed to be limited by the use of shielding and procedural controls, not by supplementing the work force. The total occupational exposure to the storage facility work force (excluding administrative and other personnel not exposed to occupational radiation) is shown in Table B-17.

7-j The death rate from occupational accidents in the storage facilities would be approximately those shown for construction and chemical industry experience in Table B-18. The total deaths estimated as the result of occupational accidents at the storage facilities are also shown in Table B-17.

B.2.2.1.6 Effects of Radioactive Effluents on Biota Other Than Man

The dose to biota from normal operation of the storage facility will be from atmospheric releases only, because no radioactive liquid effluents will be released to the environment during normal operations. These doses will be similar in magnitude to the doses to humans from atmospheric releases, which are discussed in Section B.2.2.1.3. The conclusions of the BEIR Report[14] are that no other living organisms are much more radiosensitive than humans. Therefore, no detectable radiological impact is expected in the terrestrial biota from operation of the facility.

7-b * The assumptions used for estimating occupational exposure are known to overestimate dose based upon limited experience at the GE/Morris, IL fuel storage facility and are used to ensure that the occupational health effects are not underestimated.

TABLE B-17

Occupational Radiation Exposure and Accidental Deaths During Operation of Storage Facilities[a]

	Centralized Storage — Policy Implemented (Alternative 1A)		*Decentralized Storage — Policy Implemented (Alternative 1B-1)*		*Decentralized Storage — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
Disposition Facility Startup →	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*
Operating Facilities →	*One*	*Three*	*One*	*Nine*	*One*	*Four*	*Forty-Five*	*Ninety-Three*
Total Employees	150	510	110	990	60	440	2480	5300
Employees Exposed to Radiation	110	390	83	740	45	320	1860	3980
Years of Operation	13	28	13	28	10	29	7	24
Radiation Exposure, man-rem	572	4368	432	8290	180	3712	4990	27400
Accidental Deaths[b]	0.2	1.4	0.2	2.8	0.05	1.2	1.7	9.1

a. Numbers are the totals for facilities operating.

b. Does not include accidental deaths during construction, transportation, or decommissioning.

TABLE B-18

Industrial Experience of Occupational Death Rates[26]

Industry	*Death Rate per 10^6 Man-Hours*
Transit	0.05[a]
Construction	0.17
Chemical Industry	0.03
Coal Mining, Underground	0.58
Metal Mining, Underground	0.53
Mining, Surface	0.13
Storage and Warehousing	0.00
Electric Utilities	0.08

a. The occupational death rate for the transit industry is used to estimate deaths in some facility operations. However, deaths caused during transportation of spent fuel are calculated with the probability of injury and death per truck mile or per rail car mile experienced in similar hazardous materials commerce (see Appendix C).

B.2.2.1.7 Cumulative Environmental Effect of Storage Operations

B.2.2.1.7.1 Radiological

Transport of spent reactor fuel results in direct, external radiation dose to the public along the route of transport, as well as to transport workers. In addition during transport of spent reactor fuel by truck and rail, a small percentage of the fuel elements may suffer cladding failures (Section B.2.2.1.2.1). These failures result in the release of radioactive material to the cask cavity. In this EIS, it is assumed that none of this radioactive material is released to the environment during normal transportation operations. However, a small fraction is released through the off-gas systems during cask unloading at the storage basins. This environmental release of radioactivity results in a small population radiation dose commitment and is considered as part of the storage dose in this volume.

Handling, storage, and retrieval of spent fuel at ISFS and ARB facilities are accompanied by a small number of fuel cladding failures (Section B.2.2.1.2.1). These failures result in the release of a small amount of radioactive material through ventilation systems to the environment, which is the source of environmental radioactivity during normal facility operations.

Population doses from environmental release of radioactivity from the proposed action are calculated for the local [80-km (50-mi) radius], United States, and world populations. Effects of long-lived nuclides for a 100-year period after the end of the study are included to provide an assessment of effects of persistent nuclides. The population doses from transport of fuel and from normal releases of radioactivity during facility operations and occupational exposures are summarized in Table B-19.

The health effects summarized in Table B-20 are calculated from occupational and population doses shown in Table B-19 with the EPA dose-effect factors from Table B-12.

B.2.2.1.7.2 Nonradiological Effects — Accidental Deaths

It is likely that the various operations at the storage facilities will be accompanied by occupational accidents and deaths comparable to the rate experienced in similar industries. Recent (1976) industry experience[26] is shown in Table B-18.

The expected accidental deaths for the various alternatives, based upon non-nuclear industry experience, are summarized in Table B-21. The accidental deaths for any of the alternatives considered are only about 0.002% of the 2×10^6 fatal accidental

TABLE B-19

Worldwide Population and Occupational Radiation Dose Commitment from Normal Operations of Spent Fuel Storage Basins

	Dose Commitment, man-rem											
	Disposition Facility Startup, 1985						Disposition Facility Startup, 1995					
Alternative	*Body*	*Thyroid*	*Bone*	*Lung*	*Red Marrow*	*Gonads*	*Body*	*Thyroid*	*Bone*	*Lung*	*Red Marrow*	*Gonads*
Centralized Storage -- Policy Implemented (Alternative 1A)												
Population Dose												
Transportation - External Gamma	209	-	-	-	-	209	210	-	-	-	-	210
Releases During Cask Unloading[a]	24	112	<1	19	18	16	35	121	<1	24	29	20
ISFS - Releases During Normal Operations	1041	8	122	20	54	1016	16404	81	1842	391	785	16052
Total - Population	1274	120	122	39	72	1241	16649	202	1842	415	814	16282
Occupational Dose												
Transport Workers	619	-	-	-	-	619	618	-	-	-	-	618
ISFS Facility Workers	570	-	-	-	-	570	4370	-	-	-	-	4370
Total - Occupational	1189	-	-	-	-	1189	4988	-	-	-	-	4988
Grand Total	2463	120	122	39	72	2430	21637	202	1842	415	814	21270
Decentralized Storage — Policy Implemented (Alternative 1B-1)												
Population Dose												
Transportation - External Gamma	209	-	-	-	-	209	210	-	-	-	-	210
Releases During Cask Unloading[a]	24	112	<1	19	18	16	35	121	<1	24	29	20
ISFS - Releases During Normal Operations	1041	8	122	20	54	1016	16404	81	1842	391	785	16052
Total - Population	1274	120	122	39	72	1241	16649	202	1842	415	814	16282
Occupational Dose												
Transport Workers	619	-	-	-	-	619	618	-	-	-	-	618
ISFS Facility Workers	432	-	-	-	-	432	8290	-	-	-	-	8290
Total - Occupational	1051	-	-	-	-	1051	8908	-	-	-	-	8908
Grand Total	2325	120	122	39	72	2292	25557	202	1842	415	814	25190
Decentralized Storage - Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)												
Population Dose												
Transportation - External Gamma	210	-	-	-	-	210	192	-	-	-	-	192
Releases During Cask Unloading[a]	24	112	<1	17	16	17	29	119	<1	18	24	17
ISFS - Releases During Normal Operations	81	<1	10	4	5	76	8987	37	1083	239	343	8836
Total - Population	315	112	10	21	21	303	9208	156	1083	267	367	9045
Occupational Dose												
Transport Workers	615	-	-	-	-	615	551	-	-	-	-	551
ISFS Facility Workers	180	-	-	-	-	180	3712	-	-	-	-	3712
Total - Occupational	795	-	-	-	-	795	4263	-	-	-	-	4263
Grand Total	1110	112	10	21	21	1098	13471	156	1083	267	367	13308
Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)												
Population Dose												
Transportation - External Gamma	213	-	-	-	-	213	261	-	-	-	-	261
Releases During Cask Unloading[a]	27	112	<1	21	19	18	43	128	<1	36	32	27
ARB - Releases During Normal Operations	3246	8	403	66	57	3217	21455	78	2597	731	714	21111
Total - Population	3486	120	403	87	76	3448	21759	306	2597	767	746	21399
Occupational Dose												
Transport Workers	588	-	-	-	-	588	716	-	-	-	-	716
ARB Facility Workers	4990	-	-	-	-	4990	27420	-	-	-	-	27420
Total - Occupational	5578	-	-	-	-	5578	28136	-	-	-	-	28136
Grand Total	9064	120	403	87	76	9026	49895	306	2597	767	746	49535

a. Population dose from cask unloading at storage basin and disposition facilities.

TABLE B-20

Estimated Health Effects from Spent Fuel Storage Including Effects for 100 Years Following Operations[a,b]

	Malignancies						
	Whole Body	Thyroid	Bone	Lung	Red Marrow	Genetic Effects	Total Effects
Centralized Storage -- Policy Implemented (Alternative 1A)							
Disposition Facility Startup, 1985							
Population	0.510	0.0072	0.0039	0.0016	0.0039	0.248	0.775
Occupational	0.476	-	-	-	-	0.321	0.797
Total	0.986 (0.493)	0.0072 (0.0014)	0.0039 (0.0039)	0.0016 (0.0016)	0.0039 (0.0039)	0.569	1.57
Disposition Facility Startup, 1995							
Population	6.66	0.012	0.059	0.017	0.044	3.26	10.05
Occupational	2.00	-	-	-	-	1.35	3.35
Total	8.66 (4.33)	0.012 (0.0024)	0.059 (0.059)	0.017 (0.017)	0.044 (0.044)	4.61	13.4
Decentralized Storage -- Policy Implemented (Alternative 1B-1)							
Disposition Facility Startup, 1985							
Population	0.510	0.0012	0.0039	0.0016	0.0039	0.248	0.775
Occupational	0.419	-	-	-	-	0.283	0.702
Total	0.929 (0.465)	0.0072 (0.0014)	0.0039 (0.0039)	0.0016 (0.0016)	0.0039 (0.0039)	0.531	1.48
Disposition Facility Startup, 1995							
Population	6.66	0.012	0.059	0.017	0.044	3.26	10.05
Occupational	3.54	-	-	-	-	2.39	5.93
Total	10.20 (5.10)	0.012 (0.0024)	0.059 (0.059)	0.017 (0.017)	0.044 (0.044)	5.65	15.98
Decentralized Storage -- Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)							
Disposition Facility Startup, 1985							
Population	0.126	0.0067	0.0003	0.0008	0.0011	0.061	0.196
Occupational	0.138	-	-	-	-	0.215	0.533
Total	0.444 (0.222)	0.0067 (0.0013)	0.0003 (0.0003)	0.0008 (0.0008)	0.0011 (0.0011)	0.276	0.729
Disposition Facility Startup, 1995							
E Population	3.68	0.0094	0.035	0.011	0.020	1.81	5.57
Occupational	1.71	-	-	-	-	1.15	2.86
Total	5.39 (2.70)	0.0094 (0.0019)	0.035 (0.035)	0.011 (0.011)	0.020 (0.020)	2.96	8.43
Decentralized Storage in At-Reactor Basins -- Policy Not Implemented (Alternative 2B)							
Disposition Facility Startup, 1985							
Population	1.39	0.007	0.013	0.004	0.004	0.690	2.11
Occupational	2.23	-	-	-	-	1.51	3.74
Total	3.62 (1.81)	0.007 (0.0014)	0.013 (0.013)	0.004 (0.004)	0.004 (0.004)	2.20	5.85
Disposition Facility Startup, 1995							
Population	8.70	0.018	0.083	0.031	0.040	4.28	13.2
Occupational	11.3	-	-	-	-	7.60	18.9
Total	20.0 (10.0)	0.018 (0.0036)	0.083 (0.083)	0.031 (0.031)	0.040 (0.040)	11.9	32.1

a. Health effects from radiation dose commitment during the period of operation and 100 years thereafter.

b. Fatal malignancies in parentheses.

TABLE B-21

Estimated Total Occupational Accidental Deaths from Spent Fuel Storage[a]

		Disposition Facility Startup	
		1985	*1995*
	Centralized Storage — Policy Implemented (Alternative 1A)		
	Transportation[b]	10	9
7-j	ISFS Facility[c]	1	5
	Total	11	14
	Decentralized Storage — Policy Implemented (Alternative 1B-1)		
	Transportation[b]	10	9
7-j	ISFS Facility[c]	1	8
	Total	11	17
	Decentralized Storage — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)		
	Transportation[b]	10	10
7-j	ISFS Facility[c]	<1	4
	Total	11	14
	Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)		
	Transportation[b]	10	11
7-j	ARB Facilities[c]	13	31
	Total	23	42

C *a.* Includes estimated occupational deaths during construction, operations, and decommission. Note that Table B-17 shows occupational accidental deaths occurring only within operating facilities.

b. From Table C-18.

7-j *c.* Construction (0.17 death/10^6 man-hours), operation (0.03 death/10^6 man-hours), and decommissioning (0.17 death/10^6 man-hours) (Table B-18).

deaths expected to occur in the general population of the U.S. C during the period 1983-2000, based upon the accidental death rate of 48 per 100,000 in the year 1975 (see Table B-15).

B.2.2.1.7.3 Total Health Effects

The radiological health effects (malignancies and serious genetic effects) (Section B.2.2.1.7.1) and accidental deaths (Section B.2.2.1.7.2) are summarized in Table B-22.

B.2.2.2 Thermal Effluents

Thermal effluents at a storage facility arise because of heat

- From radionuclide decay in the stored fuel
- From utilities used in the operation of the facility
- Released while producing the above utilities.

Heat is released to the environment in the form of water vapor from the facility cooling towers and the radioactive waste concentrators and by direct transfer from electric motors and other heat-producing systems. The heat discharged to the environment from all sources at the ISFS or ARB facilities is summarized in Table B-23. For perspective, the annual average solar energy incident on a single reference site of 405 hectares (1000 acres) is about 700 MW-yr.*

B.2.2.2.1 Storage Facility

The heat output from the spent fuel will depend upon the quantity of fuel stored and its age. The heat output from energy consumption will also vary to some extent with the amount of fuel stored and the throughput of fuel; however, it is conservatively assumed that the annual usage of electrical energy is constant and that the annual energy required for heating purposes is constant. The energy required for the radioactive waste concentrators[3] varies with throughput and spent fuel inventory. The facility heating and cooling systems are each assumed to be used only six months each year. The amount of heat released annually to the atmosphere from the various sources at the facility is shown in Table B-24. The amount of water vapor discharged annually to the atmosphere is shown in Table B-25.

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* Assumes average annual solar radiation of 350 langleys/day (54 Btu/hr-ft^2) estimated from Reference 27.

TABLE B-22

Estimated Total Health Effects and Accidental Deaths from Spent Fuel Storage

		Disposition Facility Startup	
		1985	*1995*
	Centralized Storage — Policy Implemented (Alternative 1A)		
E	Population Health Effects[a]	1	10
	Occupational Health Effects[a]	1	4
7-j	Occupational Accidental Deaths[b]	11	14
	Total	13	28
	Decentralized Storage — Policy Implemented (Alternative 1B-1)		
E	Population Health Effects[a]	1	10
	Occupational Health Effects[a]	1	6
7-j	Occupational Accidental Deaths[b]	11	17
	Total	13	33
	Decentralized Storage — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)		
E	Population Health Effects[a]	1	6
	Occupational Health Effects[a]	1	3
7-j	Occupational Accidental Deaths[b]	11	14
	Total	13	23
	Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)		
	Population Health Effects[a]	2	13
	Occupational Health Effects[a]	4	19
	Occupational Accidental Deaths[b]	23	42
7-j	Total	29	74

a. Calculated estimates of somatic and genetic effects from radiation exposure with EPA dose-effect factors.

7-j *b*. Tables B-21 and C-18 include construction accidental deaths.

TABLE B-23

Thermal Releases from Storage Basin Operations

Alternative	*Disposition Facility Startup*	*Total Heat Discharged, MW-yr*	
		Max Yr	*Total*
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented			
	1985	39	450
	1995	300	6900
Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)			
	1985	6.0	56
	1995	140	3400
Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)			
	1985	180	1260
	1995	470	8300

TABLE B-24

Total Heat Discharged to Atmosphere from Spent Fuel Storage, MW-yr

Disposition Facility Startup →	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*		*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-1) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*
Spent Fuel Decay Heat	68	1020	5.0	520	69	1020
Power Plant Heat						
Electrical	65	1020	8.2	500	200	1230
Process	57	860	8.0	420	180	1090
Combustion of Fossil Fuel[a]	260 (4×10^5)	4020 (6.2×10^6)	35 (5.4×10^4)	1960 (3.0×10^6)	810 (1.2×10^6)	4960 (7.6×10^6)
Total	450	6900	56	3400	1260	8300

a. The numbers in parentheses show coal consumption (tonne).

TABLE B-25

Discharges to Atmosphere from Spent Fuel Storage — Water Vapor and Ventilating Air

Disposition Facility	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*		*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
Startup →	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*
Water Vapor, tonne						
Storage Facility						
Cooling Tower[a]	1.7×10^{6}	2.6×10^{7}	1.7×10^{5}	1.3×10^{7}	5.7×10^{6}	4.0×10^{7}
Evaporator	2×10^{5}	3.0×10^{6}	2.0×10^{4}	1.6×10^{5}	6.7×10^{5}	4.7×10^{6}
Power Plant Cooling Tower	1.8×10^{6}	2.8×10^{7}	2.2×10^{5}	1.4×10^{6}	5.9×10^{6}	4.2×10^{7}
Total	3.6×10^{6}	5.7×10^{7}	4.1×10^{5}	2.8×10^{6}	1.3×10^{7}	8.7×10^{7}
Ventilating Air, m^3	4.8×10^{10}	7.5×10^{11}	7.4×10^{9}	3.4×10^{11}	2.4×10^{11}	1.7×10^{12}

a. Not all of the water evaporated in the cooling towers is the result of net heat addition by the facility. Part of the water evaporated represents heat removed from the facility ventilating air by the air-conditioning system.

B.2.2.2.2 Power Plant

An onsite steam generating plant is assumed to provide the process heat used at the facility and to meet the electrical demand. The steam plant is assumed to be fueled with coal with a heating value of 13,000 Btu/lb. The energy lost from the steam generating plant from combustion of the fossil fuel is shown in Table B-24.

A cooling tower will be required for the steam plant condenser. Water vapor discharged to the atmosphere through this cooling tower is shown in Table B-25. The coal used by the steam plant is estimated to be 374 kg/MW-hr (electrical and process heat). The total coal consumed during the entire period of operation for each alternative is shown in Table B-24.

B.2.2.3 Nonradioactive Effluents

The operation of ISFS or ARB facilities generates nonradioactive liquid, solid, and gaseous wastes. This section discusses the sources and quantities of these effluents released to the environment.

B.2.2.3.1 Gaseous Effluents

The release of nonradioactive gaseous effluents from ISFS or ARB facilities will meet all state and local requirements. Major sources of nonradioactive gaseous releases are the facility ventilating air, the boiler plant, and auxiliary diesel motor exhaust.

Ventilating Air — The ventilation system at ISFS or ARB facilities provides for once-through flow of the air. Air is filtered before entrance to the facility to remove dust particles and prevent buildup of dust inside each facility, particularly the storage pools. The filter system is assumed to remove at least 90% of the dust contained in the inlet air.

Effluent air is not filtered. The increase in dust in the ventilating air as it traverses the facility is expected to be less than that removed by the intake filter system since most of the operations in the facilities are wet so there is no net addition of dust to the atmosphere.

The release of ventilating air from the ISFS or ARB facility is presented in Table B-25.

Power Plant and Auxiliary Diesels — The nonradioactive gaseous releases from the boiler plant are estimated from the EPA guide[28] which provides conservative estimates of the quantities of pollutants released as a function of the type of fuel and the quantity of fuel burned.

For purposes of this report, it is assumed that coal with a sulfur content of 1.5% and an ash content of 10% is used. The maximum and average release rates and total releases expected for emissions from the boiler plant are shown in Table B-26.
7-i The amount of fossil fuel consumed is identified in Table B-24 for the alternatives in this EIS and is insignificant compared with total domestic consumption. The fossil fuel consumed for the alternatives considered would not significantly contribute to environmental effects due to fossil fuel combustion in the U.S. Therefore, an analysis of the relatively small incremental effects is not considered warranted.

Periodically, diesel motors for emergency power are started and tested to assure their operation in case of an emergency. The releases from these engines have been conservatively estimated on the basis of the EPA guide,[28] assuming operation of the diesel motor for two hours each month. Emissions from the diesel exhaust are given in Table B-27.

B.2.2.3.2 Liquid Effluents

Nonradioactive liquid wastes, consisting of chemical and sanitary streams generated at the ISFS or ARB facility are monitored, collected, and treated, if necessary, before discharge. The extent of monitoring and treatment is dependent upon the type of liquid effluent and government regulations. Sanitary wastes are discharged overland through a spray irrigation network after pretreatment. All other liquid wastes are discharged to the emergency cooling water pond. A summary of the liquid effluents is presented in Table B-27. Storm water is released to R River. (See Section B.1.4 for description of storm water control.)

B.2.2.4 Nonradioactive Occupational Effects

Use of chemicals of a hazardous nature is not routinely required at the storage facility. However, concentrations in air of chemicals to which the worker is exposed will normally be maintained at less than the action level values specified in Subpart Z of 29 CFR 1910[29] by engineering controls such as ventilation.

Potential exposure of the worker to these chemicals is limited because the chemicals are used in facilities designed to contain them as well as any radioactivity.

Exposures may occur in storage areas during transport of chemicals from the storage areas and during use of the chemicals predominantly for decontamination and resin regeneration.

TABLE B-26

Nonradiological Release from Steam Generating Plants[a] and Testing of Emergency Diesel Generators, tonne

Disposition Facility Startup →	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*		*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-1) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*
Steam Generating Plants						
Particulates	2.6×10^{4}	4.0×10^{5}	3.4×10^{3}	2.0×10^{5}	8.0×10^{4}	5.0×10^{5}
Sulfur Oxides	1.1×10^{4}	1.8×10^{5}	1.5×10^{3}	8.6×10^{4}	3.4×10^{4}	2.1×10^{5}
Carbon Monoxide	4×10^{2}	6.2×10^{3}	5.0×10^{1}	3.0×10^{3}	1.2×10^{3}	7.1×10^{3}
Hydrocarbons	2×10^{2}	3.1×10^{3}	2.6×10^{1}	1.5×10^{3}	6.0×10^{2}	3.8×10^{3}
Nitrogen Oxides	3×10^{3}	4.7×10^{4}	4.0×10^{2}	2.2×10^{4}	8.8×10^{3}	5.6×10^{4}
Aldehyde	1×10^{0}	1.6×10^{1}	1.3×10^{-1}	7.5×10^{0}	3.0×10^{0}	1.9×10^{1}
Testing of Emergency Diesels						
Particulates	1×10^{-1}	1.3×10^{0}	1.4×10^{-2}	6.7×10^{-1}	3.7×10^{-1}	2.2×10^{0}
Sulfur Oxides	1.6×10^{0}	2.2×10^{1}	2.4×10^{-1}	1.2×10^{1}	6.6×10^{0}	4.0×10^{1}
Nitrogen Oxides	1.4×10^{0}	1.9×10^{1}	2.0×10^{-1}	1.0×10^{1}	5.5×10^{0}	3.3×10^{1}

a. For purpose of calculating nonradiological releases, an onsite generating plant is assumed to meet the electrical and process heat requirements of the storage basin facility (Section B.2.2.2.2).

TABLE B-27

Release of Nonradioactive Liquids and Solids Wastes

Disposition Facility Startup →	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*		*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-1) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*
Liquid Wastes, tonne						
Sewer						
Sanitary[a]	1.1×10^5	8.0×10^5	3.3×10^4	7.2×10^5	9.6×10^5	5.2×10^6
Chemical	1.1×10^5	8.0×10^5	3.3×10^4	7.2×10^5	9.6×10^5	5.2×10^6
Cooling Tower Blowdown[b]						
Storage Facility	2.8×10^5	4.4×10^6	2.9×10^4	2.2×10^6	9.2×10^5	5.4×10^6
Steam Plant	3.0×10^5	4.8×10^6	3.8×10^4	2.3×10^6	9.8×10^5	5.7×10^6
Solid Wastes, m^3	4.0×10^3	3.0×10^4	1.0×10^3	2.5×10^4	3.0×10^4	1.7×10^5

a. 40 gallons/man-day.

b. Blowdown is estimated to be 17% of the water evaporated.

When concentrations are above an action level, routine monitoring is required rather than audit monitoring. When threshold limit values are exceeded, workers will wear personal protective equipment including respiratory protection as prescribed in Subpart Z of 29 CFR 1910.[29] Engineering controls would be added or modified to reduce transient high concentrations to less than threshold limit values. Records are required for each worker exposed to chemicals at concentrations greater than threshold limit values.

B.2.2.5 Radiation Effects from Abnormal Events

In this section, the releases of radioactive materials to the environment from postulated accidents at the ISFS or ARB facility are assessed in terms of dose commitment to a hypothetical individual living near the basin site and receiving the maximum dose.

Safe storage of spent fuel is the primary design and operational goal of the storage facility. Protection against the occurrence of accidents at the storage facility is provided through proper design, manufacture, and operation, as well as through a highly developed quality assurance program which helps establish and maintain the necessary integrity of the systems. Deviations that may occur are handled by protective systems designed to place and hold the affected system in a safe condition.

8-c NRC regulations require emergency response plans to be
prepared as part of the NRC licensing. The staff at an ISFS or
ARB facility will be technically skilled in the operation of the
safety and confinement systems. They will be trained to handle
all types of emergencies. Although earthquakes and other disasters
that exceed design-basis provisions are extremely unlikely, the
staff will, nonetheless, be trained to take whatever action is
necessary to maintain the facility in a safe condition or mitigate
8-c the effects of these disasters by reducing the release of radio-
nuclides and thereby minimizing the consequences.

B.2.2.5.1 Release of Radioactive Material

A wide range of accidents postulated for an ISFS or ARB
facility have been analyzed. Those accidents which result in
radioactive releases from the facility are classified either as
operating accidents or severe accidents, depending upon the
release potential and the frequency of occurrence. Operating
incidents are discussed in the section on normal releases
(Section B.2.2.1 of this appendix). Severe accidents are dis-
8-b cussed in the following paragraphs. The analysis does not
8-c take credit for reduction in releases after accidents by
emergency response of operating personnel. None of the accidents
analyzed is expected to result in near-term biological effects
of any significance.

Tornado and Earthquake — The basins will be designed as Category 1 seismic structures and, as such, designed to 1) resist rupture causing excessive loss of water, and 2) support and prevent all massive equipment, such as cranes, etc., from falling into the basins, thus causing damage to the spent fuel during
C the design-basis earthquake. The water shielding the fuel will mitigate the effect of tornadic or other wind-driven missiles.
8-d Of the credible wind-driven missiles that could penetrate pool water and cause damage to fuel, only an object like a utility pole would have the combination of buoyancy, mass, cross-sectional area, and velocity to penetrate the water shielding and potentially cause damage to stored fuel.[30] Because of this protection, the basin roof is of light industrial construction that may blow away in tornadic winds.

WASH-1300[31] provides information on the number of tornadoes expected each year (from experience in a 1° by 1° square). These vary from zero to five tornadoes per year in the United States. Based upon frequency information, the probability of a tornado striking a point is 3.3×10^{-3} per year or less. If one assumes that the ISFS or ARB facility will be located in a region of approximately 2.5 tornadoes per year, the chance that the ISFS or ARB will be struck by a tornado is about 1.6×10^{-3}. The ISFS or ARB facility will withstand the low intensity tornado but, as indicated above, high intensity tornadoes will blow away the roof over the basin. The generic facility basin roof is assumed to blow away at 200 mph. Based upon WASH-1300,[31] winds exceeding 200 mph occur during a tornado 1.5% of the time. Thus, the tornado with winds exceeding 200 mph will have a frequency of the order of magnitude of 10^{-5} per year.

For the postulated accident, the tornado makes a single pass across the facility and the roof blows away, exposing the pool water. Passage of the tornado is assumed to raise 1.3×10^{-3} tonnes of water per square foot of storage basin[32] and associated radioactivity from the storage basins. The radwaste treatment systems are tornado-proof and therefore undamaged. The radioactivity release with the water is distributed as follows: ^{53}Fe = 4%, ^{60}Co = 5%, ^{90}Sr = 1%, ^{134}Cs = 12%, ^{137}Cs = 78%. The total radioactivity released at each facility is shown in Table B-28.

Criticality — A criticality incident in a basin facility is an unlikely event because equipment and processes are designed to prevent such incidents. Safe spacing is assured in storage basins by physically spacing the fuel assemblies in storage racks in a safe pattern even if one is dropped. Process systems and controls are designed to prevent assembly of an unsafe array. There have been no criticality accidents in spent fuel storage pools.

TABLE B-28

Radionuclides Released with Basin Water During Postulated Tornado, Ci

Disposition Facility Startup →	*Centralized Storage — Policy Implemented (Alternative 1A)*		*Decentralized Storage — Policy Implemented (Alternative 1B-1)*		*Decentralized Storage — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*
Nuclides								
^{53}Fe	1.9×10^{-4}	5.8×10^{-4}	1.9×10^{-4}	1.9×10^{-4}	1.9×10^{-5}	1.9×10^{-4}	3.8×10^{-5}	5.7×10^{-5}
^{60}Co	2.4×10^{-4}	7.2×10^{-4}	2.4×10^{-4}	2.4×10^{-4}	2.4×10^{-5}	2.4×10^{-4}	4.8×10^{-5}	7.2×10^{-5}
^{90}Sr	0.48×10^{-4}	1.4×10^{-4}	0.48×10^{-4}	0.48×10^{-4}	0.48×10^{-5}	0.48×10^{-4}	0.96×10^{-5}	1.4×10^{-5}
^{134}Cs	5.8×10^{-4}	17.3×10^{-4}	5.8×10^{-4}	5.8×10^{-4}	5.8×10^{-5}	5.8×10^{-4}	11.6×10^{-5}	17.4×10^{-5}
^{137}Cs	37.4×10^{-4}	112×10^{-4}	37.4×10^{-4}	37.4×10^{-4}	37.4×10^{-5}	37.4×10^{-4}	74.8×10^{-5}	112×10^{-5}

In a quarter century, and some 500 plant-years of experience, there have been only four major criticality accidents. Two of these occurred in a plutonium scrap recovery operation and two in highly enriched uranium operations. The last one was in the year 1964. The magnitude of these criticality accidents has ranged from 1.3×10^{17} to 4×10^{19} fissions, and in no case has the release been of an explosive nature.[32] Nevertheless, a criticality accident of 1×10^{18} fissions is postulated in the storage basin with a frequency of occurrence of 10^{-5}/yr.[32] The excursion is assumed to occur at the bottom of a storage basin and to involve four PWR assemblies (the maximum weight of UO_2 handled together in the facility). The cladding is assumed to rupture on all fuel elements, releasing the gap activity to the basin water. (Although it is unlikely that four PWR assemblies at the reference burnup could become critical, the inventory of fission gas is assumed at the reference burnup.) All volatiles formed during the excursion are assumed to be released to the basin water. The accident will be terminated by relocation of the fissile materials causing the mass to reach a noncritical configuration by thermal and/or mechanical changes. All the particulate material and 99% of the halogens are assumed to be retained by the basin water.

The assumed release of fission gas from the fuel inventory is as follows: $^{85}Kr = 4.9 \times 10^{3}$ Ci, $^{129}I = 6.8 \times 10^{-5}$ Ci, $^{3}H = 1.0 \times 10^{1}$ Ci, $^{14}C = 3.7 \times 10^{-2}$ Ci, and small amounts of fission products.

B.2.2.5.2 Assumption and Transport Models

The meteorological dispersing conditions during short-term releases from accidents are taken from Regulatory Guide 1.3.[33] The nearest individual (member of the population) to a generic ISFS facility is about 0.8 km (0.5 mi). The relative concentration factor (X/Q for the point of maximum exposure of an individual [0.8 km (0.5 mi) from release point] is 9×10^{-4} sec/m^3 for a ground-level release and 5×10^{-5} sec/m^3 for a release from the 45-m (150-ft) exhaust stack.

As seen in Figure B-3 the nearest individual (member of the population) to an ARB is about 0.16 km (0.1 mi). The relative concentration factor (X/Q) for the point of maximum exposure to an individual outside the 0.16-km (0.1-mi) exclusion area is 1.6×10^{-2} sec/m^3 for a ground-level release and 7×10^{-5} sec/m^3 for a release from the 45-m (150 ft) exhaust stack.

B.2.2.5.3 Maximum Dose to an Individual

The dose commitment calculated is the maximum received by a hypothetical individual at the site boundary. The maximum dose to this hypothetical individual is shown in Table B-29.

TABLE B-29

Summary of Maximum Dose and Dose Risk to an Individual from Postulated Accidents

Disposition Facility Startup →	*Centralized Storage — Policy Implemented (Alternative 1A)* 1985	1995	*Decentralized Storage — Policy Implemented (Alternative 1B-1)* 1985	1995	*Decentralized Storage — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)* 1985	1995	*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)* 1985	1995
Maximum Dose,[a] mrem/accident								
Tornado								
Body	1.9×10^{-3}	5.7×10^{-3}	1.9×10^{-3}	1.9×10^{-3}	1.9×10^{-4}	1.9×10^{-3}	3.8×10^{-4}	3.8×10^{-4}
Bone	9.0×10^{-3}	2.7×10^{-2}	9.0×10^{-3}	9.0×10^{-3}	9.0×10^{-4}	9.0×10^{-3}	1.8×10^{-3}	1.8×10^{-3}
Thyroid	-	-	-	-	-	-	-	-
Criticality								
Body	2.0×10^{1}	2.0×10^{1}	2.0×10^{1}	2.0×10^{1}	2.0×10^{1}	2.0×10^{1}	2.0×10^{1}	2.0×10^{1}
Bone	9.7×10^{-4}	9.7×10^{-4}	9.7×10^{-4}	9.7×10^{-4}	9.7×10^{-4}	9.7×10^{-4}	9.7×10^{-4}	9.7×10^{-4}
Thyroid	1.3×10^{0}	1.3×10^{0}	1.3×10^{0}	1.3×10^{0}	1.3×10^{0}	1.3×10^{0}	1.3×10^{0}	1.3×10^{0}
Dose Risk,[a] mrem/year								
Tornado								
Body	1.9×10^{-8}	5.7×10^{-8}	1.9×10^{-8}	1.9×10^{-8}	1.9×10^{-9}	1.9×10^{-8}	3.8×10^{-9}	3.8×10^{-9}
Bone	9.0×10^{-8}	2.7×10^{-7}	9.0×10^{-8}	9.0×10^{-8}	9.0×10^{-9}	9.0×10^{-8}	1.8×10^{-8}	1.8×10^{-8}
Thyroid	-	-	-	-	-	-	-	-
Criticality								
Body	2.0×10^{-4}	2.0×10^{-4}	2.0×10^{-4}	2.0×10^{-4}	2.0×10^{-4}	2.0×10^{-4}	2.0×10^{-4}	2.0×10^{-4}
Bone	9.7×10^{-9}	9.7×10^{-9}	9.7×10^{-9}	9.7×10^{-9}	9.7×10^{-9}	9.7×10^{-9}	9.7×10^{-9}	9.7×10^{-9}
Thyroid	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}	1.3×10^{-5}

a. Summation of inhalation and immersion dose.

B.2.2.5.4 Annual Risk to Maximum Offsite Individual

Accidents have occurred in spent fuel receiving or similar facilities; however, a review and analysis of incidents occurring in government and commercial nuclear facilities encompassing something over 100,000 reports indicate no instance of injury to a member of the general public.[33]

The annual risk of releases from the postulated accidents to the maximum offsite individual is the product of frequency of the accident and the release. The risk is shown in Table B-29.

B.2.2.6 Generation of Radioactive Wastes

The operation of spent nuclear fuel storage facilities will generate liquid, solid, and gaseous radioactive wastes. Liquid and solid wastes are collected for treatment and ultimate disposal. Gaseous wastes are released to the atmosphere as discussed in Section B.2.2.1.2 of this appendix. All wastes generated during operation of the facility are assumed to be non-TRU (<10 nCi/g).[34] TRU isotopes that are released to the basin water are retained in the basin as crud and are removed during decontamination and decommissioning of the facilities (Appendix B, Section B.2.3). Treatment and packaging of wastes are described in Reference 3.

About 95% by volume of the radioactive wastes generated at the facility is solid material and includes ventilation filters, rags, protective clothing, plastic, wood, rubber, failed equipment, and similar equipment. Wet wastes at the facility arise primarily from operation of the water treatment and decontamination systems and consist of filter sludges, ion-exchange regeneration solutions, and detergent solutions that are concentrated in the evaporator. About 98% of the total radioactivity content of the wastes is contained in these concentrated solutions. The volumes of waste requiring further treatment are given in Table B-30.

6-g From the information on individual ISFS facilities shown in Table B-30, the volume of LLW ranges from about 800 to 660,000 cubic meters over the campaign. Operation of the ISFS facilities beyond the year 2000 will of course result in generation of more LLW. The total volume of LLW from ISFS operations will be small compared with that generated by reactor operations.[34] Thus, overall management of LLW will not be significantly changed by the Spent Fuel Storage Policy. To emphasize this point, the above 800 to 660,000 cubic meters of LLW could be accommodated in about 0.1 to 14 acres of burial ground space; alternatively, it would only exhaust from about 0.4 to 19% of the remaining capacity in the commercial burial ground at Barnwell, SC (Chem-Nuclear Services).

TABLE B-30

Volumes of Secondary Radioactive Waste from Operation of Each ISFS Facility, m^3

Disposition Facility Startup →	*Centralized Storage – Policy Implemented (Alternative 1A)*		*Decentralized Storage – Policy Implemented (Alternative 1B-1)*		*Decentralized Storage – Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin – Policy Not Implemented (Alternative 2B)*	
Description	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*
General Trash	9.3×10^3	1.3×10^5	9.3×10^3	6.8×10^4	7.2×10^2	6.8×10^4	5.0×10^2	1.4×10^3
Wet Waste	3.8×10^2	6.3×10^3	3.8×10^2	3.2×10^3	3.0×10^1	3.2×10^3	2.1×10^1	6.0×10^1
Failed Equipment	2.4×10^2	3.6×10^3	2.4×10^2	1.8×10^3	1.8×10^1	1.8×10^3	1.3×10^1	3.6×10^1

B.2.3 Decontamination and Decommissioning

Several decommissioning alternatives are possible for retired nuclear facilities.[35] These include

- Protective storage mode
- Entombment mode
- Dismantlement mode
- Combinations of the above modes

Selection in this volume of a reference mode for decommissioning the ISFS facilities is for the purpose of enabling environmental assessment. This is not meant to foreclose on the other alternatives.

The reference decommissioning mode assumed for a storage basin facility is immediate dismantlement after facility shutdown. Activities assumed to have been carried out during shutdown include the removal of all spent fuel from the site and the processing, packaging, and removal of all radioactive wastes. Dismantlement includes decontamination and removal of residual radioactivity and restoration of the site to nearly prefacility condition. These activities are assumed to be completed within about 18 months after facility shutdown. In general, the environmental impacts are expected to be less than similar impacts during facility construction and operation. Nonradiological effects are compared and, then, radiological effects are described.

The major impact on local communities will be those social and economic effects usually associated with a loss in employment. The operating force at an individual ISFS or ARB facility will be reduced from about 60 to 180 employees (depending upon the facility size) to about 30 to 90 (principally for decontamination activities) during dismantlement operations. Subcontractor work force of about 50 people (peak force) will be employed during a six-month period for demolition and site restoration.

Air quality and noise effects during demolition and site restoration will be similar to those during facility construction. Noise, dust, and vehicular emissions will be at maximum levels (Section B.2.1) during demolition, loading of concrete rubble, and backfilling operations. However, only about 10% of the amount of the original construction work is involved in decommissioning activities. Water requirements during dismantlement (for sanitary purposes, radioactive decontamination, and dust control) are expected to decrease when compared with the amounts used for cooling spent fuel during normal operations (about 210 m^3/day or 56,000 gal/day for a 6000 MTU ISFS).

Potential radiological effects of decommissioning will depend upon the amount and isotopic content of radioactivity remaining in the facilities after shutdown. An order of magnitude estimate of this residual inventory is shown in Table B-31 for the policy alternatives. The estimate assumes that:

- Spent fuel that had been stored would be 15 years old at shutdown
- 0.5% of stored fuel had leaked 0.01% of its radioactivity
- Basin cleanup during normal and shutdown operations had removed 99% of the released radioactivity.

TABLE B-31

Estimated Inventory of Radionuclides in Storage Basin Facilities at Shutdown, Ci

Disposition Facility	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*		*Decentralized Storage with Discharge Capability Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
Startup →	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*
Activation Products						
^{55}Fe	9.6×10^{-4}	9.2×10^{-3}	8.3×10^{-5}	4.3×10^{-3}	9.6×10^{-4}	9.2×10^{-3}
^{60}Fe	2.3×10^{-2}	2.3×10^{-1}	2.0×10^{-3}	1.0×10^{-1}	2.3×10^{-2}	2.3×10^{-1}
^{59}Ni	1.0×10^{-4}	9.7×10^{-4}	8.8×10^{-6}	4.5×10^{-4}	1.0×10^{-4}	9.7×10^{-4}
^{63}Ni	1.3×10^{-2}	1.3×10^{-1}	1.2×10^{-3}	5.9×10^{-2}	1.3×10^{-2}	1.3×10^{-1}
Subtotals	3.8×10^{-2}	3.6×10^{-1}	3.3×10^{-3}	1.7×10^{-1}	3.8×10^{-2}	3.6×10^{-1}
Fission Products						
^{90}Sr	1.4×10^{0}	1.4×10^{1}	1.3×10^{-1}	6.5×10^{0}	1.4×10^{0}	1.4×10^{1}
^{90}Y	1.4×10^{0}	1.4×10^{1}	1.3×10^{-1}	6.5×10^{0}	1.4×10^{0}	1.4×10^{1}
^{99}Tc	3.8×10^{-4}	3.7×10^{-3}	3.3×10^{-5}	1.7×10^{-3}	3.8×10^{-4}	3.7×10^{-3}
^{106}Ru	4.6×10^{-4}	4.4×10^{-3}	4.0×10^{-5}	2.0×10^{-3}	4.6×10^{-4}	4.4×10^{-3}
^{106}Rh	4.6×10^{-4}	4.4×10^{-3}	4.0×10^{-5}	2.0×10^{-3}	4.6×10^{-4}	4.4×10^{-3}
^{113m}Cd	1.3×10^{-4}	1.2×10^{-3}	1.1×10^{-5}	5.7×10^{-4}	1.3×10^{-4}	1.2×10^{-3}
^{125}Sb	5.0×10^{-3}	4.8×10^{-2}	4.3×10^{-4}	2.2×10^{-2}	5.0×10^{-3}	4.8×10^{-2}
^{125m}Te	2.0×10^{-3}	2.0×10^{-2}	1.8×10^{-4}	9.2×10^{-3}	2.0×10^{-3}	2.0×10^{-2}
^{134}Cs	4.1×10^{-2}	3.9×10^{-1}	3.5×10^{-3}	1.8×10^{-1}	4.1×10^{-2}	3.9×10^{-1}
^{137}Cs	2.0×10^{0}	2.0×10^{1}	1.8×10^{-1}	9.1×10^{0}	2.0×10^{0}	2.0×10^{1}
^{137m}Ba	1.9×10^{0}	1.8×10^{1}	1.6×10^{-1}	8.5×10^{0}	1.9×10^{0}	1.8×10^{1}
^{147}Pm	5.6×10^{-2}	5.4×10^{-1}	4.8×10^{-3}	2.5×10^{-1}	5.6×10^{-2}	5.4×10^{-1}
^{151}Sm	3.0×10^{-2}	2.9×10^{-1}	2.6×10^{-3}	1.3×10^{-1}	3.0×10^{-2}	2.9×10^{-1}
^{152}Eu	1.4×10^{-4}	1.4×10^{-3}	1.2×10^{-5}	6.4×10^{-4}	1.4×10^{-4}	1.4×10^{-3}
^{154}Eu	9.6×10^{-2}	9.2×10^{-1}	8.3×10^{-3}	4.3×10^{-1}	9.6×10^{-2}	9.2×10^{-1}
^{155}Eu	6.3×10^{-4}	6.0×10^{-5}	5.4×10^{-5}	2.8×10^{-3}	6.3×10^{-4}	6.0×10^{-5}
Subtotals	7.1×10^{0}	6.8×10^{1}	6.1×10^{-1}	3.2×10^{1}	7.1×10^{0}	6.8×10^{1}
Transuranics						
^{239}Np	4.6×10^{-4}	4.4×10^{-3}	3.9×10^{-5}	2.0×10^{-3}	4.6×10^{-4}	4.4×10^{-3}
^{238}Pu	6.8×10^{-2}	6.6×10^{-1}	5.9×10^{-3}	3.1×10^{-1}	6.8×10^{-2}	6.6×10^{-1}
^{239}Pu	8.6×10^{-3}	8.3×10^{-2}	7.5×10^{-4}	3.9×10^{-2}	8.6×10^{-3}	8.3×10^{-2}
^{240}Pu	1.3×10^{-2}	1.2×10^{-1}	1.1×10^{-3}	5.7×10^{-2}	1.3×10^{-2}	1.2×10^{-1}
^{241}Pu	1.4×10^{0}	1.3×10^{1}	1.2×10^{-1}	6.0×10^{0}	1.4×10^{0}	1.3×10^{1}
^{241}Am	4.9×10^{-2}	4.7×10^{-1}	4.2×10^{-3}	2.2×10^{-1}	4.9×10^{-2}	4.7×10^{-1}
^{242m}Am	2.2×10^{-4}	2.2×10^{-3}	1.9×10^{-3}	1.0×10^{-1}	2.2×10^{-4}	2.2×10^{-3}
^{242}Am	2.2×10^{-4}	2.2×10^{-3}	1.9×10^{-5}	1.0×10^{-3}	2.2×10^{-4}	2.2×10^{-3}
^{243}Am	4.6×10^{-4}	4.4×10^{-3}	3.9×10^{-5}	2.0×10^{-3}	4.6×10^{-4}	4.4×10^{-3}
^{242}Cm	1.8×10^{-4}	1.8×10^{-3}	1.6×10^{-5}	8.2×10^{-4}	1.8×10^{-4}	1.8×10^{-3}
^{244}Cm	3.4×10^{-2}	3.2×10^{-1}	2.9×10^{-3}	1.5×10^{-1}	3.4×10^{-2}	3.2×10^{-1}
Subtotals	1.5×10^{0}	1.5×10^{1}	1.3×10^{-1}	6.8×10^{0}	1.5×10^{0}	1.5×10^{1}
Totals	8.6×10^{0}	8.3×10^{1}	7.5×10^{-1}	3.9×10^{1}	8.6×10^{0}	8.3×10^{1}

Potential radiation dose to man in the surrounding environment from release during dismantling of small fractions of this inventory to airborne and aquatic pathways (Appendix A) is the principal concern.

The major radiological impact, which has no counterpart in normal operations, is associated with the presumed discharge of slightly contaminated storage basin water into R River in the reference environment (Appendix A). This aqueous release contains a small fraction of the residual radioactivity,* and a portion of it is assumed to reach man in the reference environment through use of the river water. The resulting radiation doses are shown in Table B-32.

For the airborne pathways to the surrounding populations, it is assumed that 1×10^{-7} of the inventory shown in Table B-31 is released to the atmosphere during decontamination and decommissioning activities.** The resulting radiation doses are shown in Table B-33.

The calculated health effects (malignancies and genetic effects) from these potential radiation doses (Tables B-32 and B-33) are shown in Table B-34. The number of effects due to decommissioning is small, ranging from 0.0007 to 0.053 for the several alternatives.

Beneficial impacts of decommissioning will include termination of land and water use at each facility. When decommissioning of the ISFS site has been completed, the 4-km^2 site area at each location may be released for other uses. It is likewise assumed that upon completion of decommissioning of ARB facilities, this area can be returned to the same status that existed before construction of the ARB facility. Release of the site for other use will depend upon the decommissioning of the adjacent reactor.

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* By facility design,[3] radioactivity in basin water is maintained at $\leq 2 \times 10^{-4}$ Ci/m^3. At the conclusion of operation, continued circulation of basin water through the cleanup system after the fuel is removed is expected to reduce the maximum radioactivity level by about a factor of 10. The amounts of basin water and the curies released are given in Table B-32.

** This estimate (1×10^{-7} of the inventory) is based on the assumption that all airflow from decontamination activities is passed through two stages of HEPA filtration before release to the atmosphere. Most of the inventory is recovered and sent to storage before dismantlement is initiated.

TABLE B-32

Dose Commitments from Aqueous Release of Storage Basin Water During Decommissioning

Disposition Facility	*Centralized Storage — Policy Implemented (Alternative 1A)*		*Decentralized Storage — Policy Implemented (Alternative 1B-1)*		*Decentralized Storage — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
Startup →	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*
Operating Facilities →	*One*	*Three*	*One*	*Nine*	*One*	*Four*	*Forty-five*	*Ninety-three*
Total water discharged[a], m^3	16,000	126,600	16,000	144,000	1,820	64,000	16,000	126,600
Curies released, % of inventory[b]	3.7	3.1	3.7	3.1	4.9	3.2	3.7	3.1
Year Basin Water Released	1996	2011	1996	2011	1993	2012	1989-1994	1999-2008
Maximum Individual Dose, mrem[c]								
Whole body	3.6×10^{-2}	9.3×10^{-2}	3.6×10^{-2}	9.3×10^{-2}	4.1×10^{-3}	3.6×10^{-2}	6.0×10^{-3}	9.0×10^{-3}
Bone	2.1×10^{-1}	5.7×10^{-1}	2.1×10^{-1}	5.7×10^{-1}	2.4×10^{-2}	2.1×10^{-1}	3.5×10^{-2}	5.2×10^{-2}
Thyroid	1.3×10^{-7}	3.3×10^{-7}	1.3×10^{-7}	3.3×10^{-7}	1.4×10^{-8}	1.3×10^{-7}	2.1×10^{-8}	7.2×10^{-8}
Gonads	4.8×10^{-7}	1.3×10^{-6}	4.8×10^{-7}	1.3×10^{-6}	5.5×10^{-8}	4.7×10^{-7}	8.0×10^{-8}	1.2×10^{-7}
80-km Population Dose, man-rem[d]								
Whole body	4.3×10^{0}	3.7×10^{1}	4.3×10^{0}	3.7×10^{1}	4.7×10^{-1}	1.9×10^{1}	7.2×10^{-1}	1.0×10^{0}
Bone	1.4×10^{2}	1.2×10^{3}	1.4×10^{2}	1.2×10^{3}	1.6×10^{1}	6.4×10^{2}	2.3×10^{1}	3.5×10^{1}
Thyroid	2.0×10^{-5}	1.7×10^{-4}	2.0×10^{-5}	1.7×10^{-4}	2.2×10^{-6}	8.7×10^{-5}	3.3×10^{-6}	5×10^{-6}
Gonads	3.8×10^{-5}	3.3×10^{-4}	3.8×10^{-5}	3.3×10^{-4}	4.3×10^{-6}	1.7×10^{-5}	6.3×10^{-6}	9.5×10^{-6}

a. Basin water containing 2×10^{-5} Ci/m^3 is released to R River in the reference environment (Appendix A).

b. The respective inventories are shown in Table B-31, this section.

c. Maximum individual drinks 2 L/day and consumes 18 kg/yr of fish from R River (downstream of release point).

d. 85% of the population within the 80-km reference environment drinks 2L/day and consumes 0.11 kg/yr of fish from R River (downstream of release point).

TABLE B-33

Dose Commitments from Release of Particulates to Atmosphere During Decommissioning (Ground Level Release)[a]

Disposition Facility	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*		*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin - Polity Not Implemented (Alternative 2B)*	
Startup →	*1985*	*1995*	*1985*	*1995*	*1985*	*1995*
Operating Facilities →	*One*	*Three*[c]	*One*	*Four*	*Forty-five*	*Ninety-three*
Year Particulates Released →	*1996*	*2011*	*1993*	*2012*	*1989 - 1995*	*1999 - 2008*
Maximum Individual Dose, mrem[3 b]						
Body					3.8×10^{-7}	5.7×10^{-7}
Inhalation	2.3×10^{-6}	7.4×10^{-6}	2.0×10^{-7}	2.6×10^{-6}	6.0×10^{-7}	9.0×10^{-7}
Foods	3.6×10^{-6}	1.2×10^{-5}	3.1×10^{-7}	4.0×10^{-6}	5.5×10^{-6}	8.2×10^{-6}
Contaminated Ground - γ	3.3×10^{-5}	1.1×10^{-4}	2.9×10^{-6}	3.8×10^{-5}		
Total	3.9×10^{-5}	1.3×10^{-4}	3.4×10^{-6}	4.5×10^{-5}	6.4×10^{-6}	9.5×10^{-6}
Bone					1.1×10^{-5}	1.7×10^{-5}
Inhalation	7.0×10^{-5}	2.3×10^{-4}	6.1×10^{-6}	7.9×10^{-5}	1.4×10^{-5}	2.1×10^{-5}
Foods	8.4×10^{-5}	2.7×10^{-4}	7.3×10^{-6}	9.5×10^{-5}		
Total	1.5×10^{-4}	5.0×10^{-4}	1.3×10^{-5}	1.7×10^{-4}	2.5×10^{-5}	3.8×10^{-5}
Local Population (80-km radius) Dose, man-rem						
Body					1.3×10^{-6}[b]	1.9×10^{-6}[b]
Inhalation	7.7×10^{-6}	8.1×10^{-5}	6.6×10^{-7}	3.8×10^{-5}	1.6×10^{-6}[b]	2.5×10^{-6}[b]
Foods	1.0×10^{-5}	1.1×10^{-4}	8.6×10^{-7}	4.9×10^{-5}	1.5×10^{-5}[b]	2.2×10^{-5}[b]
Contaminated Ground - γ	9.1×10^{-5}	9.6×10^{-4}	7.9×10^{-6}	4.5×10^{-4}		
Total	1.1×10^{-4}	1.2×10^{-3}	9.4×10^{-6}	1.8×10^{-4}	1.8×10^{-5}[b]	2.7×10^{-5}[b]
Bone					3.8×10^{-5}[b]	5.7×10^{-5}[b]
Inhalation	2.3×10^{-4}	2.4×10^{-3}	2.0×10^{-5}	1.1×10^{-3}	4.0×10^{-5}[b]	6.0×10^{-5}[b]
Foods	2.4×10^{-4}	2.6×10^{-3}	2.1×10^{-5}	1.2×10^{-3}		
Total	4.7×10^{-4}	4.9×10^{-3}	4.2×10^{-5}	2.3×10^{-3}	7.8×10^{-5}[b]	1.1×10^{-4}[b]
U. S. Population (less local) Dose, man-rem						
Body						
Inhalation	4.2×10^{-6}	4.4×10^{-5}	3.6×10^{-7}	2.1×10^{-5}	4.2×10^{-6}	4.4×10^{-5}
Foods	6.6×10^{-6}	7.0×10^{-5}	5.7×10^{-7}	3.3×10^{-5}	6.6×10^{-6}	7.0×10^{-5}
Contaminated Ground - γ	6.0×10^{-5}	6.3×10^{-4}	5.1×10^{-6}	3.0×10^{-4}	6.0×10^{-5}	6.3×10^{-4}
Total	7.1×10^{-5}	7.4×10^{-4}	6.0×10^{-6}	3.5×10^{-4}	7.1×10^{-5}	7.4×10^{-4}
Bone						
Inhalation	1.2×10^{-4}	1.3×10^{-3}	1.0×10^{-5}	5.9×10^{-4}	1.2×10^{-4}	1.3×10^{-3}
Foods	1.6×10^{-4}	1.7×10^{-3}	1.4×10^{-5}	7.9×10^{-4}	1.6×10^{-4}	1.7×10^{-3}
Total	2.8×10^{-4}	3.0×10^{-3}	2.4×10^{-5}	1.4×10^{-3}	2.8×10^{-4}	3.0×10^{-3}
Total Population Dose, man-rem						
Body						
Inhalation	1.2×10^{-5}	1.0×10^{-4}	1.0×10^{-6}	5.9×10^{-5}	1.2×10^{-5}	1.3×10^{-4}
Foods	1.7×10^{-5}	1.8×10^{-4}	1.4×10^{-6}	8.2×10^{-5}	1.7×10^{-5}	1.8×10^{-4}
Contaminated Ground - γ	1.5×10^{-4}	1.6×10^{-3}	1.3×10^{-5}	7.5×10^{-4}	1.5×10^{-4}	1.6×10^{-3}
Total	1.8×10^{-4}	1.9×10^{-3}	1.5×10^{-5}	8.9×10^{-4}	1.8×10^{-4}	1.9×10^{-3}
Bone						
Inhalation	3.6×10^{-4}	3.7×10^{-3}	3.0×10^{-5}	1.7×10^{-3}	3.6×10^{-4}	3.7×10^{-3}
Foods	3.9×10^{-4}	4.2×10^{-3}	3.5×10^{-5}	2.0×10^{-3}	3.9×10^{-4}	4.2×10^{-3}
Total	7.5×10^{-4}	7.9×10^{-3}	6.5×10^{-5}	3.7×10^{-3}	7.5×10^{-4}	7.9×10^{-3}

a. Release is 1×10^{-7} of inventories shown in Reference 6 of this section.

b. For each facility.

c. For alternative 1B-1 there are nine operating facilities in 1995.

TABLE B-34

Calculated Health Effects in Surrounding Populations from Radiation Dose Commitments[a] Caused by Decommissioning

Disposition Facility Startup →	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*		*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-1) or Policy Not Implemented (Alternative 2A)*		*Decentralized Storage in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*
From Aqueous Releases[b]	6.2×10^{-3}	5.3×10^{-2}	7.0×10^{-4}	2.8×10^{-2}	6.2×10^{-3}	5.3×10^{-2}
From Atmospheric Releases[c]	9.6×10^{-8}	1.0×10^{-6}	8.1×10^{-9}	4.7×10^{-7}	9.6×10^{-8}	1.0×10^{-6}
Total	6.2×10^{-3}	5.3×10^{-2}	7.0×10^{-4}	2.8×10^{-2}	6.2×10^{-3}	5.3×10^{-2}

a. Number of serious somatic and genetic effects calculated by using EPA risk factor shown in Section B.2.2.1.4.

b. From dose commitments shown in Table B-32.

c. From dose commitments shown in Table B-33.

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APPENDIX C

TRANSPORTATION

Present generation transportation systems and casks are designed for transporting spent fuel that is cooled about a 0.5 year. In this analysis, these casks are assumed to be used to transport spent fuel cooled longer than four to five years. Future transportation systems may be developed specifically for spent fuel cooled four to five years or longer. Such casks are expected to have larger capacities than casks designed for short-cooled fuel and probably the degree of shielding provided will be decreased. Therefore, radiation dose rates from these new casks may be slightly higher than those assumed in this analysis.
C The analysis estimated the dose rates for various cooling times of spent fuel in casks designed to meet DOT radiation limits for spent fuel cooled for about 0.5 year. However. the capacity of new casks is expected to be larger than that of existing cask designs; therefore, fewer trips are required.

Commercial fabrication of spent fuel casks has been curtailed
9-b for lack of firm implementation plans for spent fuel transfers. In this study, a program for spent fuel storage is assumed to include lead times sufficient to fabricate the required casks. These lead times are about 18 months for existing designs of truck casks and about 24 months for existing designs of rail casks. Past experience indicates that an estimated six to eight years could be required to design, test, license, and then fabricate
C a fleet of newly designed casks. However, expediting by the vendor could significantly shorten the length of time required to deliver a fleet of casks.

Rail facilities are assumed to be available to the nuclear industry to take advantage of large casks that have larger load-to-cask-weight ratios. Adequate resolution of current regulatory problems and issues, such as special trains, emergency preparedness, and state and local restrictions are also assumed. These institutional and regulatory issues are discussed in the next section.

C.1 Institutional and Regulatory Issues

C.1.1 Federal Regulations and Institutional Issues

11-b Overseeing the transportation of radioactive materials in the U.S. is a joint responsibility of the Department of Transportation (DOT) and the Nuclear Regulatory Commission (NRC). The Interstate Commerce Commission is responsible for economic regulations, but DOT and NRC are primarily responsible for safety impacts regarding shipments of nuclear materials. State or local requirements are normally auxiliary regulations that pertain to

11-b transportation routes and highway load limits or regulations that require additional safety measures.

Regulations issued by the NRC and DOT overlap to some degree; however, a memorandum of understanding issued on June 9, 1979[1] supersedes a 1973 agreement, and generally delineates the authority of the DOT as setting standards for marking, labeling, shipping safety (radiation levels, temperatures, etc.), regulating shippers and carriers, and approving different packages as suitable for transporting radioactive materials. The authority of the NRC was set forth as reviewing and approving shipping containers and special transport controls for fissile Type B and large quantities of radioactive materials as defined by Code of Federal Regulations, Title 49, Part 173.393 (49 CFR 173.393).[2]

Major regulations for transporting radioactive materials are set forth in Code of Federal Regulations, Title 10, Part 20 (10 CFR 20),[3] "Standards for Protection Against Radiation"; in 10 CFR 71,[4] "Packaging of Radioactive Materials for Transport and Transportation of Radioactive Material Under Certain Conditions"; and in 49 CFR 173,[2] "Shippers - General Requirements for Shipment and Packagings."

The general NRC criteria for packaging and shipping radioactive materials are given in 10 CFR 71[4] Subparts B, C, and D. Because of the large-quantity designation for irradiated fuel shipments, spent fuel casks must also be designed to meet hypothetical accident conditions applied sequentially (10 CFR 71,[4] Appendix B). The hypothetical accidents and the resultant cask response, as set forth, represent a reasonably conservative estimate of conditions resulting from a severe transportation accident. Criteria for design of spent fuel casks specify allowable radiation levels, criticality safety measures, heat dissipation requirements, and the requirement that the cask must prevent loss or disposal of spent fuel under normal operating and hypothetical accident conditions.

NRC regulations for radiation exposure limits and contamination control during transportation of radioactive materials are included in 10 CFR 20.[3] This set of regulations requires a receiver to check casks for transferable contamination within three hours after receipt and to notify the carrier and the NRC immediately if contamination levels exceed permissible limits for surface contamination.

10-a NRC regulations in Code of Federal Regulations, Title 10, Part 73 (10 CFR 73),[5] "Physical Protection of Plants and Materials," cover the physical security and safeguard aspects of radioactive shipments. These regulations were revised effective July 16, 1979, to require physical protection of irradiated reactor fuel in transit.[6] The revised requirements include 1) advanced NRC approval of the transport route which avoids, where practicable, 10-a heavily populated areas, 2) procedures for coping with threats and safeguard emergencies, 3) arrangements with law enforcement authorities along the route for response to an emergency, 4) scheduling of shipments with stops only for refueling and obtaining provisions, and 5) escort of the vehicle by trained individuals.

11-b DOT regulations for transportation of radioactive materials are given in 49 CFR 170-179.[2] These regulations set the criteria for radiation levels, surface temperatures, surface contamination levels, bill of lading information, labeling, placarding, shipper certification, accident response, general packaging, and foreign shipments into and from the United States.

Regulations require that notification must be given to DOT immediately following any accident, and a detailed report must be submitted within 15 days.

The Federal agency that has the principal economic regulatory authority over nuclear transportation is the Interstate Commerce Commission (ICC). ICC regulates the rates, charges, and conditions of truck, rail, and barge line services operating in interstate and foreign commerce. ICC regulations define three types of carriers: 1) private carriers, which transport their own goods and are exempt from ICC regulation; 2) contract carriers, which selectively transport other people's goods and are subject to limited ICC regulation; and 3) common carriers, which transport goods for the general public in accordance with ICC certificates of public convenience and necessity. Even though transportation safety is primarily the domain of DOT and NRC, some ICC activity may also have safety impacts.

Pending regulatory and institutional issues that may affect transportation include:

- The adequacy of emergency-response planning in the event of an accident.
- Safeguards and security measures during transport of spent fuel and wastes.
- Routing of transportation of radioactive material.
- Restrictions imposed by rail carriers.
- Insurance and liability for consequences of accidents.
- Definition of Federal-state responsibilities and Federal pre-emption of state regulations that impede commerce including hazardous materials, among which is radioactive materials.

11-b Reference 7 further discusses some applicable Federal regulations summarized above.

C.1.2 State and Local Regulations and Issues

State and local regulations on transportation used in standard commerce are normally limited to restrictions and requirements on size and type of vehicle traffic. However, recently, some states and localities have adopted or are considering regulations on nuclear material shipment to include at least the following:

a) Routing restrictions, speed limits, or blanket prohibitions on shipments
b) Advance notification of shipments and approval by states
c) Inspection of shipments
d) Pilot vehicles or escorts
e) Emergency preparedness by state officials
f) Regulations on gross vehicle weight and dimensions.

The effect of these restrictions on transportation of spent fuel will vary from state-to-state and may seriously impede the transportation of spent fuel and radioactive wastes.

As a result of these restrictions and prohibitions, shipments of radioactive materials must be routed for much longer distances or must be routed through higher population densities than are located along the highway route preferred by the carrier. The shipments are effectively slowed down resulting in greatly increased travel time. As a consequence, the cost of shipment is significantly increased and the radiation exposure of the transport crew and general population is proportionately increased.

C.1.3 Routing Restrictions — State and Federal

9-a
11-b Weight oriented restrictions on truck transportation of spent fuel are similar to any non-nuclear transportation of heavy loads. General restrictions are imposed by some states, especially for overweight loads. Routing restrictions relating to the physical protection of spent fuel shipments by truck have recently been imposed by NRC (10 CFR 73[5]). DOT regulations require transport of radioactive materials with no unnecessary delays (49 CFR 177.853).[2] If the truck must be parked for any length of time, warning devices must be placed as specified in 40 CFR 397[8] in addition to surveillance by the motor vehicle operator or another qualified representative of the motor carrier. Shipments of spent fuel and wastes are preferentially routed on interstates, limited access highways, bypasses and four-lane highways to avoid urban areas as much as possible, because accident frequencies are much lower than those on other highways and emergency response is more readily available on the interstate highways.

Spent fuel casks transported by rail are similar to heavy
11-b loads regularly transported in routine railroad commerce, including
9-a large loads of hazardous nonradioactive materials. Routes are fixed by rail locations, and urban areas cannot be readily bypassed by alternative routes. Certain routine restrictions (not specifically pertinent to radioactive materials) may also be imposed by the states or the ICC, for example, those dictated by poor track conditions in some areas.

The recent initiative of a public rule-making proceeding by DOT (Docket HM-164 "Highway Routing of Radioactive Material")[9] is an important step toward resolution of routing restrictions. DOT has been urged by the Government Accounting Office (GAO) and other government agencies to proceed expeditiously to examine the desirability of Federally prescribed routing requirements for highway, rail, and possibly barge shipments of spent fuel, as well as the question of what degree state and location restrictions are appropriate.

NRC has modified 10 CFR 73[5] with the intention of upgrading the physical protection requirements during transportation of spent fuel by truck and rail. The revised regulations require NRC to approve shipping routes and to specify escort surveillance and emergency response training.

C.1.4 Response to Emergencies

11-b After a transportation accident in the U.S., carriers of
8-e radioactive material are required to follow DOT-prescribed procedures[10] designed to mitigate the consequences. DOT regulations require prompt reporting of any transportation incident involving shipment of radioactive material in which fire, breakage, spillage, or suspected radioactive contamination occurs. The regulations also specify guidelines for remedial actions in situations involving actual or suspected release of radioactivity from a shipping container. Vehicles used for transporting radioactive material must be monitored after each shipment; they may not be returned to service until the dose rate on accessible surfaces is below prescribed levels, and no significant removable radioactive surface contamination is evident.

An intergovernmental radiological assistance program[11,12] provides personnel equipped to monitor radiation and trained to act as advisors to aid in radiological incidents such as a transportation accident involving nuclear material. The Federal radiological assistance program is coordinated by the Office of Environmental Compliance and Overview of DOE. The program provides a mechanism whereby 13 Federal agencies coordinate their radiological emergency activities with the activities of state and local health departments, and police, fire, and civil defense agencies.

11-b In the event of a transportation accident, trained personnel
8-e from the radiological assistance program are available to:

- Evaluate the radiological health hazard
- Minimize personnel exposure to radiation and/or radioactive materials
- Minimize the spread of radioactive contamination
- Minimize damaging effects on property
- Assist in carrying out emergency rescue and first-aid procedures necessary to save life and minimize injury
- Provide technical information to appropriate authorities and medical advice on the treatment of injuries complicated by radioactive contamination
- Provide information to the public as quickly as possible to minimize undue public alarm and to assist in the orderly conduct of emergency activities.

The response capability of state and local agencies for emergency situations currently varies greatly. The status of emergency preparedness of state and local response groups (police, fire protection, civil defense, etc.) is currently of concern to numerous state and local legislative bodies and is expected to result in legislative actions.

C.2 Generic Transportation Equipment and Methods

Shipping casks are available for both truck and rail transport of irradiated spent fuel from the current generation of LWRs. Either PWR or BWR fuel can be shipped in most of the spent fuel casks by using different fuel baskets; however, some baskets are designed only for a particular fuel type. Table C-1 gives information about casks that are currently available or licensed for
C spent fuel shipments in the United States. Reference 7, Section III, describes these casks. Twelve legal-weight truck casks and six rail casks of the types described in Table C-1 have been built.
9-c Spent fuel might also be shipped on the inland waterways of the U.S. by barge.

The choice between rail, truck, or barge for shipping the spent fuel is largely determined by costs, convenience, and handling requirements at reactor and storage basins. Rail casks have a significantly larger payload than truck casks. However, truck shipments normally require less turnaround time than rail or barge shipments. Although the newer reactors are providing rail capabilities, about 50% of the reactors now operating in the U.S. or scheduled for completion by the year 1980 do not have rail

TABLE C-1

Licensed and Available United States Shipping Casks for Current Generation LWR Spent Fuel[a]

Cask Designation	*Number of Assemblies* *PWR*	*BWR*	*Approximate Loaded Cask, Weight, tonne*[b]	*Usual Transport Mode*	*Maximum Heat Removal, kW*
NFS-4[c]	1	2	23	Truck	11.5
NLI 1/2	1	2	22	Truck	10.6
TN-8	3	-	35	Truck[d]	35.5
TN-9	-	7	35	Truck[d]	24.5
IF-300	7	18	79	Rail[e]	76[f]
NLI 10/24	10	24	88	Rail	97[g]

a. See Reference 7.

b. Skids and other appurtenances are included.

c. The Certificate of Compliance for the NFS-4 cask includes authorization for Nuclear Assurance Corporation to fabricate casks of this design in accordance with the Nuclear Assurance Corporation Quality Assurance Program. Such casks fabricated by NAC will bear a serial number preceded by the prefix NAC.

d. Overweight permit is required by state and local agencies.

e. Truck shipment is authorized for short distances with an overweight permit.

f. Spent fuel loads are limited to a minimum cooling time of 120 days and maximum thermal content of 61.5 kW if shipped with water coolant, or 11.7 kW if shipped with air coolant.

g. Spent fuel loads are limited to a minimum cooling time of 150 days and a maximum thermal content of 70 kW thermal load.

spurs at the site. By the year 1987, about 30% of the reactors still will not have rail spurs. Many of these reactors without rail spurs can be serviced by intermodal casks,* which require overweight permits for shipping by truck to the nearest rail siding. Several studies of barge transport are now in progress.
9-c Barge transport would require hauling casks from the reactor to the barge dock on heavy haul trucks or rail spurs added for that purpose.

The environmental effects of moving rail casks by barge for a given quantity of spent fuel are about the same or slightly less than for moving the casks by rail; therefore, barging is not specifically evaluated in this volume. Also, costs of transportation by barge are greater than by rail.[13]

The assumption is made in the transportation portions of this EIS that 70% (by weight) of the United States spent fuel shipped from reactor discharge basins to ISFS facilities is shipped by rail and the rest by truck. For this analysis, the cask usage assumed for spent fuel is

- IF-300 rail casks or equivalent, for 35% of the fuel from reactor discharge basins to ISFS facilities

- NLI 10/24 rail casks or equivalent, for 35% of the fuel from reactor discharge basins to ISFS facilities and 100% of fuel from ISFS facilities to a disposition facility

- Truck casks of 25 tons or less (LWT) for 30% of the fuel from reactor discharge basins to ISFS facilities and 100% of the fuel transshipped from a reactor discharge basin to a discharge basin at another reactor site

- Truck casks of 25 tons or less are used for all transfers from reactor discharge basins to ARB facilities.

The assumed distances between sending and receiving facilities are shown in Table C-2. These distances represent maximum distances between facilities to maximize the effects of shipments.

The number of casks required for transporting spent fuel during each year of operation is shown in Table C-3 for the various options assumed in this volume for interim storage of spent fuel. A large number of truck and rail casks must be operational by the years 1983 and 1984 for options assuming full-core reserve is maintained in reactor discharge basins. If discharge capability is assumed, the large increase in need for spent fuel casks is delayed until the year 1986 or 1987.

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* Casks which may be moved by truck, rail, or barge.

TABLE C-2

Assumed Distances Between Facilities

Mode	*Sending Facility to Receiving Facility*	*Distance One Way, miles*
Truck	Reactor Discharge Basins to Other Reactor Discharge Basins	100
	Reactor Discharge Basins to ISFS Facilities	1000
	Reactor Discharge Basins to ARB Facilities	0.1
	Reactor Discharge Basins to Disposition Facility	1500
	ISFS or ARB Wastes to Burial Ground	500
Rail	Reactor Discharge Basins to ISFS Facilities	1000
	Reactor Discharge Basins to Disposition Facility	1500
	ISFS Facilities to Disposition Facility	1500

TABLE C-3

Cask Requirements[a]

Year	*Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented*				*Decentralized Storage with Discharge Capability — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*				*Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)*			
	Disposition Facility Startup				*Disposition Facility Startup*				*Disposition Facility Startup*			
	1985		*1995*		*1985*		*1995*		*1985*		*1995*	
	Truck	*Rail*	*Truck*	*Rail*	*Truck*	*Rail*	*Truck*	*Rail*	*Truck*	*Rail*	*Truck*	*Rail*
1979	6	-	6	-	6	-	6	-	3	-	3	-
1980	4		4	-	4	-	4	-	4	-	4	-
1981	4	-	4	-	4	-	4	-	4	-	4	-
1982	9	-	9	-	9	-	8	-	5	-	5	-
1983	20	12	20	8	7	-	8	1	17	-	17	-
1984	29	19	29	19	9		11	2	22	-	22	-
1985	35	21	31	20	11	2	14	5	25	2	25	-
1986	44	31	36	24	39	26	16	7	36	25	30	-
1987	49	31	40	27	41	27	23	12	40	25	34	-
1988	66	49	50	37	89	67	28	16	56	49	46	-
1989	70	52	53	39	98	77	30	19	85	74	49	-
1990	77	58	58	43	116	92	32	20	90	78	55	-
1991	84	74	63	48	85	68	36	26	93	81	62	-
1992	87	94	65	51	87	71	40	37	93	80	65	-
1993	93	97	69	55	93	73	42	29	97	84	69	-
1994	97	101	72	58	97	77	48	34	96	83	74	-
1995	105	99	78	64	105	84	51	38	97	84	80	2
1996	105	84	86	70	105	84	63	47	97	84	85	25
1997	106	84	87	70	106	84	70	53	98	84	86	25
1998	114	91	110	89	114	91	92	77	106	91	101	65
1999	115	92	115	92	115	92	110	92	107	92	123	92
2000	122	98	122	98	122	98	117	98	114	98	132	98
2004	-	-	-	137	-	-	122	105	-	-	18[b]	16[b]
2005	-	-	-	137	-	-	122	105	-	-	49	43
2006	-	-	-	137	-	-	122	105	-	-	151	130
2007	-	-	-	137	-	-	122	105	-	-	151	130
2008	-	-	-	137	-	-	-	110	-	-	151	130
2009	-	-	-	137	-	-	-	110	-	-	151	130
2010	-	-	-	119	-	-	-	110	-	-	151	130
2011	-	-	-	-	-	-	-	109	-	-	77	66

a. Assumes 80% utilization after the shipping system is firmly established. During first campaigns from reactor basins, the utilization factor probably will be about 50%.

b. Spent fuel in inventory in the ARB facilities is transported to the disposition facility after the year 2000 to deplete ARB inventory.

A relatively large number of truck casks must be operational by the year 1983 for the at-reactor storage alternative. Significant numbers of rail casks are not required until the year 1986 for disposition facility startup in the year 1985 or until the year 1996 if disposition facility startup is delayed until the year 1995. The assumed turnaround times and trips per cask used to calculate the cask requirements for transporting spent fuel are shown in Table C-4.

TABLE C-4

Assumed Parameters for Transportation Trips

Mode	*Distance One Way, miles*	*Turnaround Time, days*	*Cask Trips per Year*[a]
Rail	1000	18	16
Rail	1500	24	12
Truck	On Reactor Site	1	150[b]
Truck	100	2	100
Truck	1000	5	56
Truck	1500	7	40

a. At 80% utilization.

b. At 60% utilization.

In addition to shipments of spent fuel, wastes generated at interim storage facilities must be transported. Solid wastes generated in ISFS or ARB facilities normally contain low quantities of fission and activation products and less than 10 nCi of transuranic isotopes per gram of waste;* thus, the waste may currently be shipped to burial grounds.

Solid waste, reduced in volume by compaction or incineration, will be packaged and shipped in containers that meet DOT specifications. This solid waste is assumed to be packaged in 210-L (55-gallon) drums (meeting DOT specification 17C) and steel boxes (meeting DOT specification 7A) and shipped in enclosed truck-trailers. An average load is assumed to be 64 drums in a van, which may be shielded, or 14 drums in a lightly shielded cask. The number of steel boxes per load will depend upon the size of the boxes. Occasionally, vans with some lead placed around the walls are now used for shipments of drummed waste.

* The 10 nCi/g transuranic isotopes limit for earthen burial is currently under study and may be revised.

The small volume of ISFS wastes containing more than 10 nCi of transuranic isotopes per gram of waste will be sent to a Federal repository. These wastes are assumed to be packaged in DOT specification 17C 210-L (55-gallon) steel drums. Individual packages that exceed 0.001 Ci of transuranic isotopes will be shipped by truck in overpacks that meet Type B package standards. The overpacks may be shielded, depending upon the dose rate from the waste package.

C.3 Environmental Effects

The environmental effects from the transportation of spent fuel to ARB or ISFS facilities or to the disposition facility, and from transportation of storage basin wastes to a burial ground or disposition facility are developed in this section. The effects of cask fabrication and other nonradiological effects of transportation operations are also discussed in this section. Radiological and nonradiological effects of various options for policy implementation and no-policy implementation are shown. Truck shipments of spent fuel result in most of the environmental effects. The effects of onsite transportation from reactor discharge basins to ARB facilities are included in the operation of the ARB facilities.

C.3.1 Cask Fabrication

Casks are fabricated by manufacturers who have the capabilities to handle and machine large parts and who have established quality assurance controls required for certification of casks. Several manufacturers have the capability of pouring the quantity of lead and/or uranium that is needed for large casks. Fabrication facility capacity is limited for casting and machining large, depleted uranium cask components. However, numerous manufacturers have the capacity to fabricate the steel components for the casks. It is expected that private industry will supply the casks as required.

Cask manufacturers are assumed to control effluent concentrations of depleted uranium, lead, and steel from casting and fabrication operations to comply with state and Federal air quality limits. The quantities of materials estimated for existing cask designs during the study period for the various operations are

- steel — 2,900 to 3,900 tonnes
- lead — 8,700 to 11,400 tonnes
- depleted uranium — 490 to 690 tonnes.

C.3.2 Environmental Effects of Transportation Operations

C.3.2.1 Radiation Effects from Normal Operations

This section assesses for normal transportation operations the radiation doses to the population and to transportation workers (occupational dose). Dose estimates for the population include maximum exposure received by an individual, and the total dose received by the population exposed to radiation from the passing shipments. In addition, the local, U.S., and worldwide exposures are estimated for potential releases of washoff of residual radioactivity of cask surfaces. Exposures are evaluated for the maximum year and for the transportation of approximately 72,200 MTU of spent fuel. This section also includes estimates of the radiation effects on the biota.

C.3.2.1.1 Assumptions

The major assumptions used in the analysis are

- 30% of the spent fuel is shipped by truck, 70% by rail based upon the availability of reactor cask handling facilities. This is a conservative assumption. It is the ratio expected for shipments in the 1980s, but by the year 2000, only about 10% of the spent fuel is expected to be shipped by truck. Truck shipments result in larger population and transportation worker exposure per ton of spent fuel shipped; therefore, overestimation of truck shipments results in conservative estimates of radiation effects.

- The radiation doses to the general population, to the maximum individual along the shipping routes, and to the transportation workers are assessed with the methods developed in NUREG-0170.[14] These methods include assessment of dose to persons in vehicles traveling in the same or opposite directions of the shipments, in addition to those persons exposed as the shipment passes.

- Trucks are routed on four-lane and freeway roads to bypass high-density urban areas.

- Vehicle velocities are adjusted according to the traffic conditions expected as the shipment passes by each population group, i.e., rural, suburban, and urban.

- Shipping mode, package descriptions, length of trip, etc., are selected to maximize the effects of these shipments for the analysis in this volume.

These assumptions and other assumptions are discussed in Reference 7.

C.3.2.1.2 Releases of Radioactive Materials During Normal Shipment

Quality assurance requirements for packages containing Type B or larger quantities of radionuclides include inspection procedures to ensure that packages are properly assembled. These procedures minimize the probability of release of radioactivity during normal shipments. Conditions that could result in releases during normal operations are discussed below.

Residual contamination on cask surfaces could be washed off by rain during shipment. DOT regulations (49 CFR 173.397)[2] state that the permissible removable contamination on the package surface is 10^{-4} beta-gamma $\mu Ci/cm^2$ or 10^{-5} alpha $\mu Ci/cm^2$. Assuming this contamination level, the maximum amount of radioactivity that would be expected to be washed off the cask is expected to be about 2×10^{-6} Ci of mixed fission products. This washoff* is expected to occur during shipment of less than one cask out of a thousand, based upon experience at the Receiving Basin for Offsite Fuel at the Savannah River Plant. Use of this maximum value in this volume would then conservatively result in an estimated release of $<2 \times 10^{-9}$ Ci of mixed fission products and actinides per cask shipped.

Spent fuel cladding may fail due to mechanical damage from vibration, shock, and other stress encountered by the fuel on highways and railroads or during rail car coupling operations. If cladding fails during normal transportation, the casks will contain any gases or particulates released to the cavity of the cask. If a cask containing fuel with failed cladding is unloaded at the receiving facility, some gases and particulates would be vented to the off-gas system. (See Appendices B and D for estimates of these effects.) For this assessment, the cladding of 0.01% of the fuel elements is assumed to fail during normal transport as discussed in Reference 7.

As a result of human error, it is possible that in the shipment of a large number of drums of solid wastes (TRU wastes), some of the drums may not be properly closed. The estimate is that one in about 10,000 packages may not be properly closed when shipped.[15] The drums of low-level TRU wastes are shipped in a protective overpack. If an improperly closed drum were to open

* From cask and transport equipment to highway or railroad.

within the overpack, the cement matrix containing the waste material would limit the extent of the contamination of the surrounding waste containers and the inside surfaces of the overpack. No significant releases would result in transit if the overpack is properly closed. The overpack would be opened at the disposition facility under controlled conditions where any release of radionuclides would be vented to the building ventilation system which is filtered through HEPA filters. The probability per shipment of a drum being improperly closed and the overpack being improperly closed is estimated to be less than 10^{-6}. The maximum release from such an overpack is estimated to be about 10^{-5} Ci, primarily actinides.

The probability of a spent fuel cask not being properly closed is reduced by the requirements for quality assurance procedures, package testing before and after loading operations, and inner and outer closures. The probability of improper closure that is not detected by quality assurance inspections is estimated at 10^{-8}.

C.3.2.1.3 Radiation Dose Commitment from Shipments

The direct radiation doses are assessed for casks containing spent fuel and for casks and packages containing wastes. Shipments of spent fuel are assumed to be in casks designed to meet DOT limits (ten mrem/hr at six feet from the carrier) when the spent fuel is cooled about 0.5 year. Table C-5 gives the assumed dose rate from spent fuel and waste shipments. Dose commitment to the population resulting from normal transportation is from direct radiation and from radionuclides washed from contaminated casks.

TABLE C-5

Typical Dose Rate in Transit at 6 Feet from Truck or Rail Car

	Assumed Dose Rate, mrem/hr				
Shipping Package	*0.5-Year Cooling*	*2-Year Cooling*	*5-Year Cooling*	*10-Year Cooling*	*25-Year Cooling*
Spent Fuel Casks	10	3.5	1.6	0.9	0.6
Low-Level Non-TRU Wastes	*a*	*a*	2	1.5	1.0

a. None of these shipments are expected at this cooling time.

Direct Radiation Commitment — Direct radiation from shipments of spent fuel and wastes results in a small dose commitment to the population along the shipping route and to those occupying vehicles in interacting traffic. Direct radiation exposures from passing shipments expose the local population only and are shown in Tables C-6, C-8, and C-10 for disposition facility startup in the year 1985, and in Tables C-7, C-9, and C-11 for disposition startup in the year 1995.

Overall Transportation Dose Commitment to Maximum Individual — The overall maximum dose to an individual in the general population from normal transportation activities for the campaign is shown in Table C-12. The individuals who receive the maximum exposures live beside a highway or railroad at the perimeter of the disposition facility. The table shows that doses from contamination washoff is insignificant compared with radiation to residents along the shipping route.

Overall Transportation Dose Commitment to Local, U.S., and and World Populations — The overall dose commitments to local and U.S. populations from normal transportation activities are shown in Table C-13. The majority of the dose commitment is to the local population and is primarily caused by direct radiation from truck shipments.

C.3.2.1.4 Health Effects to the General Population

The cumulative population dose commitment to the general population varies from 200 to 260 man-rem for various options, and these options are estimated to cause 0.12 to 0.16 health effects. These health effects are based upon EPA health effect factors as discussed in Appendix B.

C.3.2.1.5 Occupational Exposures

The cumulative dose to transportation workers varies from 550 to 720 man-rem for the various options analyzed as shown in Table C-14. A truck driver who annually makes 50 trips of 1500 miles each way with spent fuel is estimated to accumulate a
E | maximum dose of 0.3 rem. This accumulation is the maximum estimated annual dose to any transportation worker.

TABLE C-6

Direct Radiation Doses from Normal Transportation of Spent Fuel — Centralized Storage (Alternative 1A) or Decentralized Storage (Alternative 1B-1) — Policy Implemented — Disposition Facility Startup in 1985

	Dose, man-rem			
		General Population		
Shipment Type	*Transportation Workers*	*Local, 80-km Radius*	*U.S., Less Local*	*Total*
Truck				
Reactor Basins to Reactor Basins and Return	51.0	2.5	-	2.5
Reactors to ISFS Basin	33.0	1.2	11.0	12.0
Waste ISFS to Burial Ground	5.9	0.44	1.8	2.2
Reactors to Disposition Facility	490.0	13.0	180.0	190.0
Total - Truck	580.0	17.0	190.0	210.0
Rail				
Reactors to Disposition Facility	35.0	0.41	5.7	6.1
Reactors to ISFS Basin	2.3	0.04	0.33	0.37
ISFS Basin to Disposition Facility	2.5	0.03	0.40	0.43
Total - Rail	40.0	0.48	6.4	6.9
Total - Truck and Rail	620.0	17.0	200.0	220.0

TABLE C-7

Direct Radiation Doses from Normal Transportation of Spent Fuel — Centralized Storage (Alternative 1A) or Decentralized Storage (Alternative 1B-1) — Policy Implemented — Disposition Facility Startup in 1995

	Dose, man-rem			
		General Population		
Shipment Type	*Transportation Workers*	*Local, 80-km Radius*	*U.S., Less Local*	*Total*
Truck				
Reactor Basins to Reactor Basins and Return	51	2.5	-	2.5
Reactors to ISFS Basin	300	11	99	110
Waste ISFS to Burial Ground	67	5.2	21	26
Reactors to Disposition Facility	150	3.9	55	59
Total - Truck	570	23	180	200
Rail				
Reactors to Disposition Facility	11	0.12	1.7	1.8
Reactors to ISFS Basin	22	0.25	3.4	3.7
ISFS Basin to Disposition Facility	19	0.23	3.2	3.4
Total - Rail	52	0.60	8.3	8.9
Total - Truck and Rail	620	24	190	210

TABLE C-8

Direct Radiation Doses from Normal Transportation of Spent Fuel — Decentralized Storage with Discharge Capability — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A) — Disposition Facility Startup in 1985

	Dose, man-rem			
		General Population		
Shipment Type	*Transportation Workers*	*Local, 80-km Radius*	*U.S., Less Local*	*Total*
Truck				
Reactor Basins to Reactor Basins and Return	51	2.5	-	2.5
Reactors to ISFS Basin	2.7	0.1	0.8	0.9
Waste ISFS to Burial Ground	0.3	0.02	0.1	0.1
Reactors to Disposition Facility	520	11	190	200
Total - Truck	570	14	190	200
Rail				
Reactors to Disposition Facility	37	0.43	6.1	6.5
Reactors to ISFS Basin	0.2	<0.01	0.03	0.03
ISFS Basin to Disposition Facility	0.2	<0.01	0.04	0.04
Total - Rail	37	0.43	6.2	6.6
Total - Truck and Rail	610	14	200	210

TABLE C-9

Direct Radiation Doses from Normal Transportation of Spent Fuel — Decentralized Storage with Discharge Capability — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A) — Disposition Facility Startup in 1995

	Dose, man-rem			
		General Population		
Shipment Type	*Transportation Workers*	*Local, 80-km Radius*	*U.S., Less Local*	*Total*
Truck				
Reactor Basins to Reactor Basins and Return	48	2.3	-	2.3
Reactors to ISFS Basin	140	5.2	47	52
Waste ISFS to Burial Ground	36	2.8	11	14
Reactors to Disposition Facility	290	8.0	110	120
Total - Truck	510	18	170	190
Rail				
Reactors to Disposition Facility	20	0.25	3.5	3.8
Reactors to ISFS Basin	10	0.17	1.5	1.7
ISFS Basin to Disposition Facility	7.9	0.10	1.4	1.5
Total - Rail	38	0.52	6.4	7.0
Total - Truck and Rail	550	19	180	200

TABLE C-10

Direct Radiation Doses from Normal Transportation of Spent Fuel Shipments — Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B) — Disposition Facility Startup in 1985

	Dose, man-rem			
		General Population		
Shipment Type	*Transportation Workers*	*Local, 80-km Radius*	*U.S., Less Local*	*Total*
Truck				
Reactor Basins to Reactor Basins and Return (Transshipments)	4.5	0.22	-	0.22
ARB Basin to Disposition Facility	50	1.2	17	18
Waste ARB to Burial Ground	6.0	0.44	1.8	2.2
Reactors to Disposition Facility	490	12	180	190
Total - Truck	550	14	200	210
Rail				
Reactors to Disposition Facility	35	0.41	5.7	6.1
ARB Basin to Disposition Facility	3.4	0.04	0.52	0.56
Total - Rail	38	0.45	6.2	6.7
Total - Truck and Rail	590	14	210	220

TABLE C-11

Direct Radiation Doses from Normal Transportation of Spent Fuel Shipments — Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B) — Disposition Facility Startup in 1995

	Dose, man-rem			
		General Population		
Shipment Type	*Transportation Workers*	*Local, 80-km Radius*	*U.S., Less Local*	*Total*
Truck				
Reactor Basins to Reactor Basins and Return (Transshipments)	4.5	0.22	-	0.22
ARB to Disposition Facility	460	11	160	170
Waste ARB to Burial Ground	68	5.3	21	26
Reactors to Disposition Facility	150	3.8	53	57
Total - Truck	680	20	230	250
Rail				
Reactors to Disposition Facility	11	0.12	1.7	1.8
ARB to Disposition Facility	33	0.38	5.3	5.7
Total - Rail	44	0.50	7.0	7.5
Total - Truck and Rail	720	20	240	260

TABLE C-12

Maximum Individual Whole Body Dose from Transportation

Alternative	*Disposition Facility Startup*	*Source of Commitment*	*Maximum Year Dose, mrem*	*Total for Period Dose, mrem*
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented	1985	Direct Radiation	1.9×10^{-1}	2.0×10^{0}
		Contamination Washoff[a]	6.0×10^{-5}	7.0×10^{-4}
		Total	1.9×10^{-1}	2.0×10^{0}
	1995	Direct Radiation	1.9×10^{-1}	8.8×10^{-1}
		Contamination Washoff[a]	6.0×10^{-5}	3.0×10^{-4}
		Total	1.9×10^{-1}	8.8×10^{-1}
Decentralized Storage with Discharge Capability — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)	1985	Direct Radiation	1.9×10^{-1}	2.1×10^{0}
		Contamination Washoff[a]	6.0×10^{-5}	$8.0 \quad 10^{-4}$
		Total	1.9×10^{-1}	2.1×10^{0}
	1995	Direct Radiation	2.0×10^{-1}	1.4×10^{0}
		Contamination Washoff[a]	6.4×10^{-5}	5.0×10^{-4}
		Total	2.0×10^{-1}	1.4×10^{0}
Decentralized Storage in At-Reactor Basins - Policy Not Implemented (Alternative 2B)	1985	Direct Radiation	1.9×10^{-1}	2.2×10^{0}
		Contamination Washoff[a]	6.0×10^{-5}	8.0×10^{-4}
		Total	1.9×10^{-1}	2.2×10^{0}
	1995	Direct Radiation	2.5×10^{-1}	2.2×10^{0}
		Contamination Washoff[a]	8.0×10^{-5}	8.0×10^{-4}
		Total	2.5×10^{-1}	2.2×10^{0}

a. Assumes the individual is exposed to contamination accumulated along one mile of the highway or railroad and that 1% is dispersed as respirable aerosol. The radionuclide distribution is assumed to be that of spent fuel.

TABLE C-13

Population Whole Body Dose Commitment from Transportation

Alternative	*Disposition Facility Startup*	*Source of Commitment*	*Population Dose Commitment, man-rem*		
			Local	*U.S., Less Local*	*Total*
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented	1985	Direct Radiation			
		Rail	0.48	6.4	6.9
		Truck	17	190	210
		Contamination Washoff	3×10^{-6}	*a*	3×10^{-6}
		Total	17	200	220
	1995	Direct Radiation			
		Rail	0.60	8.3	8.9
		Truck	23	180	200
		Contamination Washoff	3×10^{-6}	*a*	3×10^{-6}
		Total	24	190	210
Decentralized Storage with Discharge Capability — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)	1985	Direct Radiation			
		Rail	0.43	6.2	6.6
		Truck	14	190	200
		Contamination Washoff	3×10^{-6}	*a*	3×10^{-6}
		Total	14	200	210
	1995	Direct Radiation			
		Rail	0.52	6.4	6.9
		Truck	18	170	190
		Contamination Washoff	3×10^{-6}	*a*	3×10^{-6}
		Total	19	180	200
Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)	1985	Direct Radiation			
		Rail	0.45	6.2	6.7
		Truck	14	200	210
		Contamination Washoff	3×10^{-6}	*a*	3×10^{-6}
		Total	14	210	220
	1995	Direct Radiation			
		Rail	0.50	7.0	7.5
		Truck	20	230	250
		Contamination Washoff	3×10^{-6}	*a*	3×10^{-6}
		Total	20	240	260

a. Much less than dose to local population.

TABLE C-14

Occupational Exposure for Transportation Workers

Alternative	*Disposition Facility Startup*	*Occupational Exposure, man-rem* *Truck*	*Rail*	*Total*
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) Policy Implemented	1985	580	40	620
	1995[a]	570	52	620
Decentralized Storage with Discharge Capability — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)	1985	570	37	610
	1995[a]	510	38	550
Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)	1985	550	38	590
	1995[a]	680	44	720

a. A large amount of spent fuel is transported from storage basins after the year 2000.

C.3.2.1.6 Effects on Biota

During transportation of spent fuel and associated wastes, direct radiation exposures to flora and fauna are equal to or less than those to man. Therefore, this transportation causes no significant impact on the biota.

C.3.2.2 Thermal Effects

The rate of decay heat released from spent fuel casks carrying spent fuel considered in this EIS varies from about 1 to 3 kW for truck casks and from about 4 to 13 kW for rail casks depending upon the cooling time of the spent fuel being shipped. Casks for transporting short-cooled spent fuel are designed for much higher heat removal rates as shown in Table C-1. The decay heat released from various options is given in Table C-15. In addition to the decay heat released, the engine heat from combustion of petroleum fuels is shown. This latter thermal effluent exceeds the decay heat by a factor of 40 to 70 for the various options.

Thermal releases to the environment for this proposed action are insignificant. During the year of maximum shipments, vehicles used to transport spent fuel and reprocessing wastes will result in about 10^{-5} of the thermal releases from other transportation vehicles.

TABLE C-15

Thermal Release from Transportation, kW-yr

	Disposition Facility Startup	*Total Heat Release from Carrier Engine*		*Total Decay Heat from Casks*	*Total Heat Release*
Maximum Release, yearly		*Truck*	*Rail*		
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented	1985	1.3×10^4	3.9×10^3	2.9×10^2	1.7×10^4
	1995	1.3×10^4	3.9×10^3	2.9×10^2	1.7×10^4
Decentralized Storage with Discharge Capability — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)	1985	1.4×10^4	3.7×10^3	2.9×10^2	1.8×10^4
	1995	1.5×10^4	4.2×10^3	3.1×10^2	2.0×10^4
Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)	1985	1.3×10^4	3.9×10^3	2.9×10^2	1.7×10^4
	1995	1.7×10^4	6.1×10^3	3.9×10^2	2.4×10^4
Cumulative Releases					
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented	1985	1.5×10^5	4.7×10^4	3.4×10^3	2.0×10^5
	1995	1.4×10^5	7.1×10^4	5.3×10^3	2.2×10^5
Decentralized Storage with Discharge Capability — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)	1985	1.6×10^5	4.4×10^4	3.0×10^3	2.1×10^5
	1995	1.5×10^5	5.7×10^4	4.1×10^3	2.1×10^5
Decentralized Storage in At-Reactor Basins -- Policy Not Implemented (Alternative 2B)	1985	1.5×10^5	4.4×10^4	3.0×10^3	2.0×10^5
	1995	1.6×10^5	4.4×10^4	3.0×10^3	2.1×10^5

C.3.2.3 Nonradioactive Effluents

Nonradioactive effluents during transportation are combustion products from petroleum consumed by trucks and locomotives. The cumulative effluents shown in Table C-16 result from combustion of diesel fuel varying from 1.0×10^8 to 1.6×10^8 liters (2.7×10^7 to 4.3×10^7 gallons) for the various options. Maximum annual fuel consumption varies from 1.4×10^7 to 1.8×10^7 liters (3.6×10^6 to 4.8 v 10^6 gallons) for these options. The EPA emission rates in Reference 16 and fuel consumption rates in Reference 17 were used to estimate the pollutant emissions. For comparison, the consumption of petroleum by all motor vehicles was 1.1×10^{11} gallons in 1973[18] and is projected to be about twice as much in the year 2000.[19]

C.3.2.4 Nonradioactive Occupational Effects

Workers who transport spent fuel and associated waste experience the nonradioactive occupational effects typical of the trucking or rail industries. The major nonradioactive occupational effect is the chance of being injured or killed in a truck or rail accident. This is discussed in Section C.3.2.6. No other detrimental nonradiological occupational effects are anticipated.

C.3.2.5 Radiation Effects from Potential Abnormal Events

Irradiated fuel and wastes are transported in rugged casks and packages specifically designed and tested to retain the contents during minor, moderate, and severe transportation accidents. Extreme accidents, which have a very low probability of occurring, may cause breaching of the containment features of the package.

8-b The consequences (and risks) of a transportation accident are a function of the cooling time of the spent fuel. Release mechanisms and associated release fractions that determine the amount of radionuclides that are potentially released from a cask damaged after a severe transportation accident are dependent upon the cooling time of the spent fuel which determines the decay heat of the fuel. The maximum consequences potentially occur after an extreme accident severely damages a rail cask carrying 120-day cooled spent fuel. The cask cavity is filled with water as the heat transfer media, and no corrective action is assumed to be taken to cool the exterior of the cask. After two days or more have elapsed without exterior cooling, the water in the cavity may be completely released (as steam through pressure relief valves), and the spent fuel self-heats until the cladding fails.[20] Then, the decay heat of the fuel provides the driving force to release radionuclides from the fuel matrix through the cladding failure and through any breaches in the containment system of the cask.[7]

8-b In the technological documents for the draft Commercial Waste EIS, a transportation accident was evaluated for such a cask scenario, assuming spent fuel cooled about 0.5 yr,[21] and the conclusion was that the whole body dose to the maximum individual might be as great as 120 rem due to inhaled radionuclides. That scenario results in consequences that are estimated to be several orders of magnitude greater than those for credible accident scenarios involving casks (water, helium, or air filled) where the spent fuel is cooled four years or longer. Selfheating of the fuel will not cause the cladding to fail because the decay heat from spent fuel cooled four years is about 1/7 of that cooled for approximately 0.5 year.[7] For actions expected as a result of implementing the Spent Fuel Storage Policy, little (if any) short-cooled spent fuel will be transported; therefore, the probability of an accident resulting in consequence of the magnitude shown in the draft Commercial Waste EIS will be extremely small, and the associated risk will also be extremely small.

This section discusses accidents and the resulting releases
C of radioactive materials associated with transportation of spent fuel cooled 4 years or longer. The consequences of these accidents are assessed in terms of the maximum dose to an individual near
8-b the extreme accident and its risk (consequence times probability of occurrence). Radioactive materials dispersed from a damaged cask are inhaled or ingested in a short time. The dose identified for the maximum individual is protracted over a 50-year period from the radioactivity retained in the body.

C.3.2.5.1 Transportation Accidents

Statistics from experience with transportation of all hazardous
8-e materials (including LNG, gasoline, explosives, and flammable chemicals and gases) are used to estimate the frequency of transportation accidents involving radioactive materials. The probabilities and physical consequences of the spectrum of postulated
C transportation accidents for shipments of long-cooled spent fuel and past experience in shipping irradiated fuel and other radioactive materials are discussed in Reference 7.

TABLE C-16

Nonradioactive Effluents from Transportation

Alternative	*Nonradioactive Emissions, tonne* — *Disposition Facility Startup 1985* *Rail*	*Truck*	*Total*	*Disposition Facility Startup 1995* *Rail*	*Truck*	*Total*
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented						
Particulate	1.2×10^2	1.9×10^2	3.1×10^2	1.8×10^2	1.7×10^2	3.5×10^2
Sulfur Dioxide (SO_x as SO_2)	2.6×10^2	3.9×10^2	6.5×10^2	3.9×10^2	3.6×10^2	7.5×10^2
Carbon Monoxide	5.0×10^2	3.3×10^2	3.8×10^3	7.6×10^2	3.0×10^2	1.1×10^3
Hydrocarbons	4.4×10^2	5.4×10^2	9.8×10^2	6.7×10^2	4.9×10^2	1.2×10^3
Nitrogen Oxides (NO_x as NO_2)	1.7×10^3	5.4×10^3	7.1×10^3	2.6×10^3	4.9×10^3	7.5×10^3
Aldehydes (as HCHO)	2.6×10^2	4.4×10^1	3.0×10^2	3.9×10^2	4.0×10^2	4.3×10^2
Organic Acids	3.1×10^1	4.4×10^1	7.5×10^1	4.7×10^1	4.0×10^1	8.7×10^1
Decentralized Storage with Discharge Capability -- Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)						
Particulate	1.1×10^2	2.0×10^2	3.1×10^2	1.5×10^2	1.7×10^2	3.2×10^2
Sulfur Dioxide (SO_x as SO_2)	2.5×10^2	4.2×10^2	6.7×10^2	3.1×10^2	3.6×10^2	6.7×10^2
Carbon Monoxide	4.7×10^2	3.5×10^2	8.2×10^2	6.0×10^2	3.0×10^2	9.0×10^2
Hydrocarbons	4.2×10^2	5.8×10^2	1.0×10^3	5.3×10^2	4.9×10^2	1.0×10^3
Nitrogen Oxides (NO_x as NO_2)	1.6×10^3	5.8×10^3	7.4×10^3	2.1×10^3	4.9×10^3	7.0×10^3
Aldehydes(as HCHO)	2.5×10^2	4.7×10^1	3.0×10^2	3.1×10^2	4.0×10^1	3.5×10^2
Organic Acids	2.9×10^1	4.7×10^1	7.6×10^1	3.8×10^1	4.0×10^1	7.8×10^1
Decentralized Storage in At-Reactor Basins -- Policy Not Implemented (Alternative 2B)						
Particulate	1.1×10^2	2.0×10^2	3.1×10^2	1.1×10^2	2.1×10^2	3.2×10^2
Sulfur Dioxide (SO_x as SO_2)	2.4×10^2	4.2×10^2	6.6×10^2	2.4×10^2	4.4×10^2	6.8×10^2
Carbon Monoxide	4.7×10^2	3.5×10^2	8.2×10^3	4.7×10^2	3.7×10^2	8.9×10^2
Hydrocarbons	4.1×10^2	5.8×10^2	9.9×10^2	4.2×10^2	6.0×10^2	1.0×10^3
Nitrogen Oxides (NO_x as NO_2)	1.6×10^3	5.8×10^3	7.4×10^3	1.6×10^3	6.0×10^3	7.6×10^3
Aldehydes (as HCHO)	2.4×10^2	4.7×10^1	2.9×10^2	2.4×10^2	4.9×10^1	2.9×10^2
Organic Acids	2.9×10^1	4.7×10^1	7.6×10^1	2.9×10^1	4.9×10^1	7.8×10^1

8-e Even if a more severe (and less likely) accident than postulated here does occur, package failure with subsequent extensive dispersion of radioactive contents is unlikely. Carriers of radioactive materials are required to follow DOT-prescribed procedures designed to mitigate the consequences of a transportation accident as discussed in Section C.1.4. Also, an intergovernmental radiological assistance program provides personnel equipped to monitor radiation and trained to act as advisors to aid in emergency response and any clean-up following a transportation accident involving nuclear materials. See Section C.1.4 for further discussion.

C.3.2.5.2 Release of Radioactive Materials

C Transportation accidents with shipments of long-cooled spent fuel may cause fuel cladding failure, but unless the cask is breached during the accident, any radionuclide release into the cask cavity caused by the cladding failure will be contained until the cask is vented at the receiving facility. If the cask is breached, the release would occur at the accident site. If the cask is involved in a moderate or severe accident (see Reference 7 for descriptions of accident severity and frequency), fuel cladding failure is assumed to be 0.25%. Accidents of this severity can be expected at a probability of about 10^{-7} per vehicle mile, but no release is expected at the accident site. If the cask is involved in an extra severe or extreme accident, 1% of the fuel is assumed to fail. These accidents have a probability of occurrence of about 10^{-11} per vehicle mile. Even in such an accident, the probability of the cask being breached is low.

The massive, heavily shielded construction of casks is designed to survive severe accidents. Cask failure has not been experienced during transportation of spent fuel or in testing of full-scale spent fuel casks at vehicle speeds of up to 84 mph.[7] Therefore, a low probability of damage severe enough to breach a cask subjected to extreme accident conditions is assumed.

The release fractions that may be encountered in an extra
C severe or extreme accident involving long-cooled spent fuel are shown in Table C-17.

As discussed earlier, releases could occur either at the site of the accident or as the cask is vented in the receiving facility. The consequences of a release at the site of the accident are much higher than the consequences from a release that occurs under controlled conditions at the receiving site. The consequences of the accident were evaluated, assuming that the release occurred at the point of the accident. This maximizes the consequences of the accident.

TABLE C-17

Assumed Release Fractions for Shipments of Long-Cooled Spent Fuel in an Extreme Accident

Nuclides	*Fraction of Contents Released*
^{3}H	1×10^{-4}
^{85}Kr	3×10^{-3}
^{129}I	1×10^{-3}
Particulates (other fission products and actinides)	1×10^{-8}[a]

a. Conservatively assumes particulates of fission products and actinides migrate from the fuel matrix through failed cladding.

The release of radionuclides after an accident is assumed to occur at ground level under weather conditions described as Pasquill "F" (as recommended in NRC Regulatory Guide 1.3).[22] The individual who receives the maximum dose is assumed to be located 100 meters downwind of the release. Methods to calculate inhalation and submersion doses to this individual are shown in Reference 7.

C.3.2.5.3 Dose Commitment to the Maximum Individual

The maximum 50-year dose commitment to an individual downwind of an extreme accident involving an irradiated fuel rail cask containing four-year cooled fuel is 0.4 rem, whole body; 17 rem, bone; and 0.5 rem, lung.

C.3.2.5.4 Annual Risk to Maximum Individual

The annual risk to the maximum individual is the product of the dose commitment from an extreme accident and its probability of occurrence in that year. The probability of an extreme accident during the year of the maximum number of shipments of four-year cooled fuel in rail casks is estimated to be 2×10^{-5} (based upon Reference 15, adjusted for vehicle miles as described in Reference 7). Therefore, the maximum risk to the maximum individual is 7×10^{-6} rem/yr, whole body; 3×10^{-4} rem/yr, bone;

and 8 x 10^{-6} rem/yr, lung. The probability of an individual being in the vicinity of more than one accident involving a release from these shipments is very small.

Rail accidents could involve more than one rail car carrying a cask or overpack. The probability of breaching two or more cask(s) or overpack(s) in the same extreme accident is significantly lower than breaching a single cask or overpack. The cumulative risk from multiple breachings in a single accident is then only slightly higher than the values shown in this volume.

C.3.2.6 Nonradiation Effects from Potential Abnormal Events

Transportation accidents cause injuries and fatalities to truck drivers, rail crewmen, and the involved members of the general public. The estimated injuries and fatalities resulting from transportation are shown in Table C-18 for various options. About 10 fatalities may occur. These health effects are very small compared to fatalities associated with normal activities of the population and natural disasters shown in Table C-19.

C.3.3 Decontamination and Decommissioning Effects

The decontamination of casks will not add significantly to the release from the ISFS, ARB, or disposition facilities. All of these releases would occur through the facility ventilation system.

Decontamination efforts required for spent fuel casks removed from basins are a function of the cleanliness of the pool, the time the cask is submerged, and the condition of the cask surfaces. Cask decontamination will be done with hot water under pressure with the addition of approved chemicals, as required. After decontamination, the casks will be dried. A separate ventilation exhaust duct, demister, and HEPA filter is provided for the decontamination module.

The useful life of a spent fuel or waste cask is expected to be 20 to 30 years. When a cask and other transport equipment is decommissioned, it will either be adequately decontaminated for material salvage or partially decontaminated and shipped to a commercial burial ground. This analysis assumes that all of the casks will be buried.

TABLE C-18

Injuries and Fatalities in Transportation Accidents

Alternative	*Disposition Facility Startup*	*Mode*	*Total Miles*[a]	*Injuries*[b]	*Fatalities*[c]
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented	1985	Truck	1.6×10^8	140	8
		Rail	4.2×10^7	17	2
		Total		160	10
	1995	Truck	1.4×10^8	120	7
		Rail	6.4×10^7	26	2
		Total		150	9
Decentralized Storage with Discharge Capability — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)	1985	Truck	1.6×10^8	140	8
		Rail	4.0×10^7	16	2
		Total		160	10
	1995	Truck	1.5×10^8	130	8
		Rail	5.1×10^7	20	2
		Total		150	10
Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)	1985	Truck	1.6×10^8	140	8
		Rail	4.0×10^7	16	2
		Total		160	10
	1995	Truck	1.7×10^8	150	9
		Rail	4.0×10^7	16	2
		Total		170	11

a. Includes return of empty packages.

b. Assumed probabilities, 9×10^{-7}/mile for truck and 4×10^{-7}/car mile for rail.[15]

c. Assumed probabilities, 5×10^{-8}/mile for truck and 3×10^{-8}/car mile for rail.[15]

TABLE C-19

Fatalities from Accidents and Natural Disasters[23]

Event	*Fatalities Per Year*
All accidents	115,000
Motor vehicle accidents	55,000
Industrial accidents	14,000
Falls	16,000
Fires	6,500
Airplane crashes	1,600
Lightning	160
Tornadoes	90

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APPENDIX D

DISPOSITION FACILITY RECEIVING SPENT FUEL

In this appendix, the environmental effects of receiving spent fuel at the disposition facility, specifically the unloading of the fuel at this facility, is analyzed. As described in Section I of this volume, a disposition mode has not been selected, and the facilities assumed in this appendix are generic in nature but reasonable for most disposal modes that may be selected.

D.1 Atmospheric Release of Radionuclides

When fuel is unloaded, the cask is vented to the off-gas system of the facility. The exhaust air will be filtered with high-efficiency particulate filters before release to the environment through a stack assumed to be 110 m (360 ft) tall.

Spent-fuel cladding may fail during normal transportation due to mechanical damage during vibration, shock, and other stresses encountered by the fuel on highways and railroads or during rail car coupling operations. When the cask containing fuel with failed cladding is unloaded at the disposition facility, some gases and particulates will be vented to the off-gas system. For this assessment, cladding of 0.01% of the fuel elements is assumed to fail during normal transport as discussed in Reference 1. The release fractions assumed for unloading this fuel at a disposition facility are shown in Table D-1.

Radionuclide releases to the atmosphere from unloading fuel at disposition facilities are shown in Table D-2 for various options. The differences in release of individual radionuclides between options reflect differences in average cooling times of spent fuel received. (The same amount of spent fuel is received at the disposition facility in each option.)

Accidents during transportation are expected to cause a larger failure rate of fuel cladding than during normal transportation. If a cask is involved in a moderate or severe accident, fuel failure is assumed to be 0.25%. Accidents of this severity can be expected at a probability of about 10^{-7} per vehicle mile. If the cask is involved in an extra severe or extreme accident, fuel failure is assumed to be about 1%. These accidents can be expected with a probability of about 10^{-11} per vehicle mile. The cumulative release of radionuclides during venting (through the disposition facility ventilation system) of the internal atmosphere of the casks involved in transportation accidents is estimated to be two to three orders of magnitude less than the releases listed in Table D-2.

TABLE D-1

Atmospheric Release Fractions from Off-Gas Systems at a Disposition Facility Receiving Spent Fuel

Nuclide	*Fraction of Fuel Leaking*	*Fraction of Activity Released to Cask Cavity*	*Fraction to Off-Gas System*	*Fraction to Atmosphere*	*Overall Release Fraction to Atmosphere*
^{3}H	1×10^{-4}	1×10^{-2}	1	1	1×10^{-6}
^{14}C	1×10^{-4}	3×10^{-2}	1	1	3×10^{-6}
^{85}Kr	1×10^{-4}	3×10^{-1}	1	1	1×10^{-5}
^{129}I	1×10^{-4}	1×10^{-1}	1	1	1×10^{-5}
Particulates[a]	1×10^{-4}	1×10^{-4}	0.1	1×10^{-7}[b]	1×10^{-16}

a. Assumed to be other fission products and actinides.

b. Two HEPA filters in series.

TABLE D-2

Radionuclides Released to Atmosphere During Cask Venting at Disposition Facilities, Cumulative, Ci

Disposition Facility Startup →	*Centralized Storage (Alternative 1A) or Decentralized Storage With Full-Core Reserve (Alternative 1B-1) Policy Implemented*		*Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) or Policy Not Implemented (Alternative 2A)*		*Decentralized Startup in At-Reactor Basin — Policy Not Implemented (Alternative 2B)*	
	1985	*1995*	*1985*	*1995*	*1985*	*1995*
Nuclide						
^{3}H	2.7×10^{1}	1.7×10^{1}	2.8×10^{1}	2.2×10^{1}	2.8×10^{1}	2.1×10^{1}
^{14}C	1.4×10^{-1}	1.5×10^{-1}	1.4×10^{-1}	1.5×10^{-1}	1.4×10^{-1}	1.7×10^{-1}
^{85}Kr	1.8×10^{4}	1.0×10^{4}	1.8×10^{4}	1.2×10^{4}	1.8×10^{4}	1.3×10^{4}
^{90}Sr	4.6×10^{-7}	4.0×10^{-7}	5.0×10^{-7}	4.3×10^{-8}	3.4×10^{-8}	4.0×10^{-8}
^{129}I	2.7×10^{-2}	2.7×10^{-2}	2.7×10^{-2}	2.7×10^{-2}	2.7×10^{-2}	3.1×10^{-2}
^{134}Cs	3.0×10^{-7}	9.4×10^{-8}	3.2×10^{-7}	1.1×10^{-7}	6.0×10^{-9}	1.2×10^{-8}
^{137}Cs	6.4×10^{-7}	5.4×10^{-7}	6.9×10^{-7}	5.8×10^{-7}	4.7×10^{-8}	5.5×10^{-8}
^{144}Ce	8.6×10^{-8}	2.7×10^{-8}	9.4×10^{-8}	2.7×10^{-8}	6.0×10^{-10}	3.5×10^{-9}
^{147}Pm	2.1×10^{-7}	6.6×10^{-8}	2.2×10^{-7}	7.1×10^{-8}	5.2×10^{-9}	8.5×10^{-9}
^{154}Eu	3.0×10^{-8}	1.6×10^{-8}	3.4×10^{-8}	1.9×10^{-8}	1.7×10^{-12}	1.8×10^{-9}
^{237}Np	2.2×10^{-12}	2.6×10^{-12}	2.4×10^{-12}	2.4×10^{-12}	1.8×10^{-13}	2.4×10^{-13}
^{236}Pu	1.9×10^{-8}	1.9×10^{-8}	2.1×10^{-8}	1.9×10^{-8}	1.5×10^{-9}	1.8×10^{-9}
^{239}Pu	2.1×10^{-9}	2.2×10^{-9}	2.2×10^{-9}	2.4×10^{-9}	1.7×10^{-10}	2.3×10^{-10}
^{240}Pu	3.2×10^{-9}	3.4×10^{-9}	3.4×10^{-9}	3.4×10^{-9}	2.5×10^{-10}	3.3×10^{-10}
^{241}Pu	5.4×10^{-7}	3.8×10^{-7}	5.9×10^{-7}	4.3×10^{-7}	3.5×10^{-8}	3.9×10^{-8}
^{242}Pu	8.6×10^{-12}	9.4×10^{-12}	9.4×10^{-12}	9.4×10^{-12}	7.1×10^{-13}	9.2×10^{-13}
^{241}Am	5.4×10^{-9}	1.3×10^{-8}	5.9×10^{-9}	1.2×10^{-8}	7.6×10^{-10}	1.2×10^{-9}
^{242}Cm	2.1×10^{-11}	8.0×10^{-11}	2.2×10^{-11}	8.0×10^{-11}	3.1×10^{-10}	8.5×10^{-11}
^{243}Cm	2.1×10^{-11}	1.9×10^{-11}	2.2×10^{-11}	1.9×10^{-11}	1.5×10^{-12}	1.8×10^{-12}
^{244}Cm	1.2×10^{-8}	8.6×10^{-9}	1.3×10^{-8}	1.0×10^{-8}	8.1×10^{-10}	9.2×10^{-10}
^{245}Cm	2.1×10^{-12}	2.2×10^{-12}	2.2×10^{-12}	2.2×10^{-12}	1.7×10^{-13}	2.2×10^{-13}

D.2 Dose to Population

The generic disposition facility is assumed to occupy about E 4,000 hectares (10,000 acres), and the closest member of the C general population is assumed to be located 0.8 km (0.5 mile) from the facility. The normal ventilation of the facility will be exhausted through a 110-m (360-ft) stack. The relative concentration factor ($\overline{\chi}/Q$) for the 80-km (50-mi) population from this release height is 2.8×10^{-9} sec/m^3 (population weighted χ/Q) for a theoretical dispersion (undepleted cloud). A deposition velocity of 1 cm/sec is assumed for radioiodine and particulates. Dispersion assumptions used for calculating dose to the eastern U.S. population and the world population are discussed in Reference 1.

The population around the disposition facility within the 80-km (50-mi) radius is assumed to be 1,700,000 in the year 1977 distributed as shown in Figures A-1 and A-2 of Appendix A of this volume. U.S. population in the year 1977 is assumed to be about 200 million people with 80% of the total living in the eastern United States. The world population is assumed to be 4.1 billion, of which 80% is assumed to reside in the northern hemisphere and be exposed to releases which may occur from operation of this geologic disposition facility. The assumptions on population growth rates are discussed in Appendix A of this volume.

Population doses that result from releases associated with unloading spent fuel at the disposition facilities are shown in Table D-3.

TABLE D-3

Population Dose Commitment from Unloading Spent Fuel at Disposition Facilities

Alternative	*Disposition Facility Startup*	*Dose Commitment, man-rem*					
		Body	*Lung*	*Bone*	*Marrow*	*Thyroid*	*Gonads*
Centralized Storage (Alternative 1A) or Decentralized Storage with Full-Core Reserve (Alternative 1B-1) — Policy Implemented	1985	22	17	< 1	16	112	15
	1995	23	12	< 1	19	121	14
Decentralized Storage with Discharge Capabilities — Policy Implemented (Alternative 1B-2) of Policy Not Implemented (Alternative 2A)	1985	24	17	< 1	16	112	17
	1995	23	12	< 1	19	119	14
Decentralized Storage in At-Reactor Basins — Policy Not Implemented (Alternative 2B)	1985	25	19	< 1	17	112	17
	1995	29	19	< 1	22	128	19

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C APPENDIX E

ENVIRONMENTAL EFFECTS OF DELAYED DISPOSITION FACILITY (STARTUP IN THE YEAR 2010)

E.1 Purpose of Appendix

Due to the uncertainty of the government's program dealing with nuclear waste disposal problems, a delay in the opening of the first disposition facility beyond the time frame originally analyzed in this EIS is a possibility. This appendix provides the environmental analysis of interim U.S. spent fuel storage assuming the initial disposition facility is started up in the year 2010. Appendix A of Volume 3 shows the effects of a delay in the geologic repository on foreign fuel received under the U.S. Spent Fuel Storage Policy. When the draft EISs[1,2] were prepared in the latter part of the year 1977 and early 1978, the national objective was to open the first geologic repository in the year 1985. Environmental effects of interim storage of spent reactor fuels in an ISFS were thus calculated for the disposition facility operation beginning in the years 1985 and 1995. The ISFS facility effects were determined through the year 2000 to ensure that the range of actions were covered by the draft EISs. Between the time the draft documents were written and this final EIS was complete, DOE recognized that the first geologic repository might not be in operation until the mid to late 1990's.

President Carter recently announced (February 12, 1980)[3] the administration's position on nuclear waste management and estimated that the location of the first repository will be determined around the year 1985 and initial operation of the first repository would begin in the mid 1990's. DOE's input[4] to the NRC rulemaking on nuclear waste storage and disposal estimates that the first respository may be available between the years 1997-2006. To demonstrate the environmental effects of delayed repository opening beyond the year 1995, as analyzed in the body of this EIS on the Spent Fuel Storage Policy, DOE decided to prepare this Appendix to show the environmental effects associated with interim storage of U.S. power reactor fuel in ISFS facilities with the first disposition facility startup in the year 2010. The year 2010, assumed for startup of the disposition facility in this appendix, was arbitrarily selected to establish an upper limit for the environmental effects associated with storing domestic spent fuel.

For purposes of the analysis in this appendix, DOE used current predictions on the amount of electric power generation, the amount of spent fuel expected to be stored in reactor discharge basins, and the amount of spent fuel storage capacity expected to be

C required in ISFS facilities. This appendix compares the environmental effects of the delay in startup of the disposition facility if the U.S. Spent Fuel Storage Policy is implemented or not implemented. The schedule used in other parts of this EIS reflect the anticipated storage needs as developed in 1978. In this appendix, the fuel flows are based on current estimates of storage capacity requirements which are lower than assumed in other parts of this EIS. This difference can be seen in Figure E-1 and is discussed in more detail in Section II-D of this volume. The major differences are listed below.

- In this appendix, the electric generating capacity of U.S. nuclear reactors is assumed to be 276 GW_e for the year 2000 and increases to 456 GW_e by the year 2010. In the remainder of the EIS the assumed nuclear generating capacity is 380 GW_e by the end of the year 2000.

- The information in this appendix was derived from current utility estimates of storage in reactor discharge basins for the interim time period between now and about the year 1993. An average of 13 years of storage is assumed in the reactor discharge basins until the end of the study period. The utility estimate of interim storage includes plans for optimum use of reactor discharge basin space through densification, reracking, etc. The analysis in other parts of the EIS assumes less efficient storage in reactor discharge basins.

- The analysis in this appendix assumes no transshipment of spent fuel. The remainder of the EIS, with the exception of Alternative 2B, assumed limited transshipment.

The schedule for spent fuel discharged from U.S. power reactors is shown in Figure E-2 and is consistent with DOE/EIA 1979 High Growth Projection[5] through 1995. Between the years 1995 and 2010 an average annual power generating capacity addition of 18 GW_e/year was used. This is consistent with the DOE/EIA Long Range Energy Assessment Program's Series C Extension.[6]

The objective of the analysis in this appendix is to show the effect of a delayed disposition facility using DOE's current prediction of the amounts of spent fuel that may require storage. So, the fuel flow data analysis uses the same approach as is used by DOE in establishing away-from-reactor storage requirements.[7] The ISFS storage capacity was determined from the present to the early 1990's using the DISFUL computer code.[8] The code options used were those assumed by DOE for the Base Planning Case which includes maximum expansion of reactor-discharge basin capacities, no transshipment of spent fuel to other reactors and maintaining reserve storage capacity in the reactor discharge basin for a full reactor core. The installed capacity in the DISFUL data base reaches a

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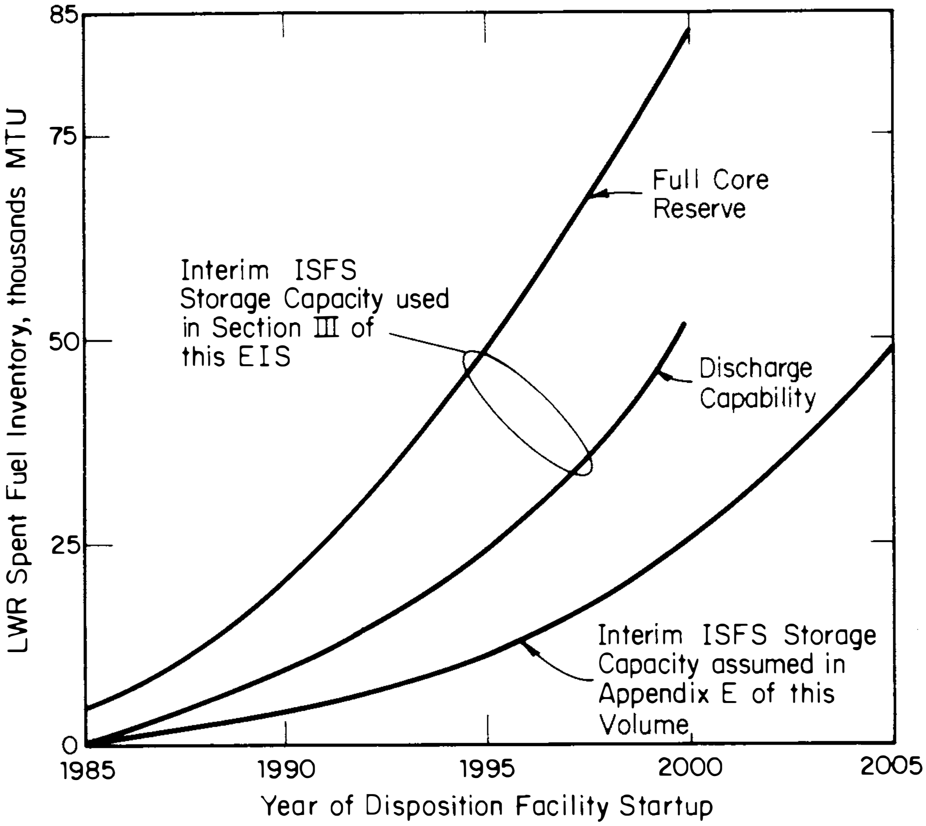

FIGURE E-1 Interim Storage Capacity Dependence upon Disposition Facility Startup

C

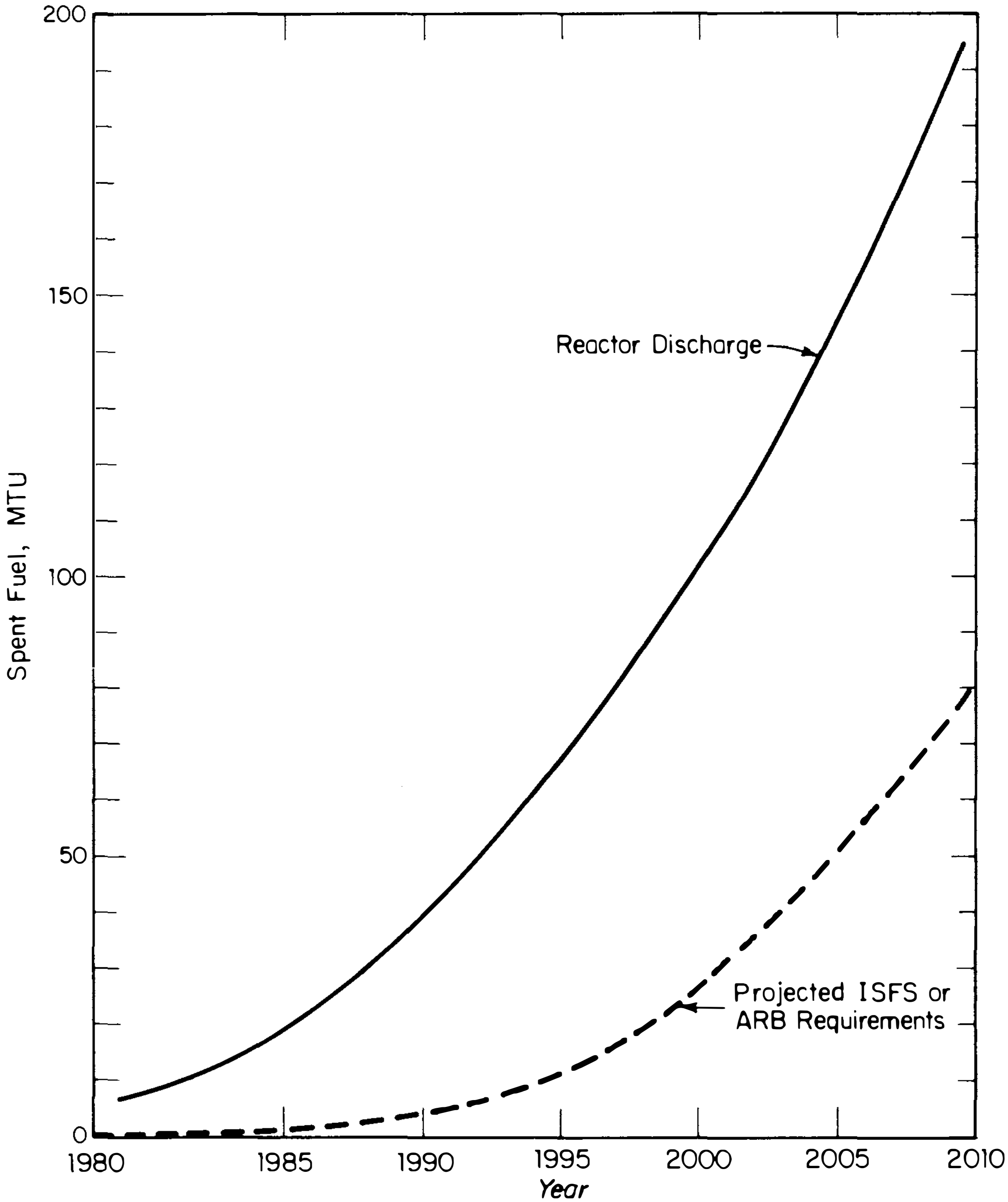

FIGURE E-2. Projected Reactor Discharges and ISFS or ARB Storage Requirements maximum of 177.7 GW_e in the year 1994. In 1994, incremental new capacity was added to follow the DOE/EIA projection. This approach developed by S. M. Stoller Corporation[9], used the DOE NUFUL computer code to determine the fuel flows from the new incremental capacity which were then added to the cumulative discharges determined by the DISFUL code. The ISFS requirements beyond the early 1990's were calculated on the basis that reactors built through the year 1990 would be able to maintain full-core reserve capacity with an average of 13 years of storage before it became necessary to ship spent fuel to ISFS facilities. This 13-year storage was determined from the last several years of storage capacity determined by the DISFUL code. It also assumes that new reactors built between the years 1990 and 2010 will be built with this average storage capacity. As new reactors are proposed, the design of these reactors will certainly consider storage capacity for the expected life of the reactors. If new reactors are constructed with storage capacities in excess of 13 years, the ISFS capacity requirement will decrease and the environmental effects shown in this appendix will thus be conservative. It is unlikely that new reactors will be constructed with less than 13 years of storage.

The alternatives used to show the environmental effects of delayed startup of the disposition facility (until the year 2010) were selected to parallel the alternatives considered in the remainder of this volume of the EIS. The alternatives of implementing the Spent Fuel Storage Policy and not implementing the policy are called Alternative 3 and Alternative 4, respectively, to help differentiate between alternatives discussed in the remainder of this volume of the EIS. Each of these two alternatives has two options to show a range of environmental effects.

The two options of Alternative 3 consider interim storage of spent fuel in centralized (Option A) or decentralized (Option B) ISFS facilities. These operations are called Alternatives 3A and 3B. Alternative 3A is similar to Alternative 1A in that spent nuclear reactor fuel accepted by the U. S. Government is stored in centralized, large, government ISFS facilities. Alternative 3B is similar to Alternative 1B in that storage is in smaller, decentralized ISFS facilities owned by the U. S. Government. In both, Alternative 3A and 3B, disposal of domestic spent fuel is assumed to begin in the year 2010.

Two options of Alternative 4 (the policy not implemented) were also analyzed. Alternative 4A is similar to 2A in that new decentralized ISFS facilities are assumed to be built by private industry, with no government involvement. Alternative 4B is similar to Alternative 2B in that it is assumed that at-reactor storage basins (ARBs) will be constructed by the utilities to store domestic fuel. Again, as in Alternative 3, the disposition facility is expected to start up in the year 2010.

C In summary, this appendix was prepared to show the environmental effects of a startup of the first disposition facility as late as the year 2010. Alternatives 3 and 4 use fuel flows that more accurately forecast expected storage than the other sections of this volume and can only be used to compare the environmental effects of implementing the policy compared to not implementing the policy. Comparative background effects are also presented. The decision of whether to implement or not implement the U.S. Spent Fuel Storage Policy is independent of when the first disposition facility opens. This decision should be determined using environmental input based on comparison of alternatives for the same disposition facility startup date. It was therefore concluded that use of different fuel flows (in this appendix compared with the remainder of Volume 2) will not affect the comparative data developed for a disposition facility startup in the years 1985 or 1995 as analyzed in the remainder of Volume 2. Use of the more recent estimates of fuel flows and storage requirements add to the scope of the EIS by providing more current estimates of the effects of implementing the U.S. Spent Fuel Storage Policy.

E.2 Alternative Description

Interim storage capacity requirements for ISFS facilities and ARB facilities for all alternatives considered in this appendix were developed for a year 2010 startup of the first disposition facility. During the first four years of operation of this disposition facility, spent fuel is assumed to be received at partial capacity, as was assumed in the remainder of Volumes 2 and 3 of this EIS. The design receiving rate is achieved in the year 2014, the fifth year of operation. In the year 2015, after the first disposition facility is up to the full receiving rate and all disposition facility operations have been demonstrated, a second disposition facility is assumed to start up. Two years later, in 2017, the third disposition facility is assumed to start up. This schedule for startup is thought to be reasonable for geologic repositories and satisfactory for other disposition facilities. The alternatives described in this section were developed using this schedule for disposition facility startup.

E.2.1 Policy Implemented

Under the "Policy Implemented" alternative (Alternative 3), the U.S. Government would accept title to domestic spent fuel. Two options associated with Alternative 3 were examined under the scenario of a year 2010 startup date for the spent fuel disposition facility. In option A (called Alternative 3A), centralized storage is provided in large independent spent fuel storage (ISFS) facilities (18,000 MTU capacity) owned or operated

C by the U.S. Government. In option B (called Alternative 3B), decentralized storage of domestic spent fuel is provided in small government-owned ISFS facilities (6000 MTU capacity). In both options, the disposal of domestic spent fuel is assumed to occur in U.S. disposition facilities with initial startup in the year 2010.

E.2.1.1 Alternative 3A

In Alternative 3A (centralized storage), domestic irradiated reactor fuel is assumed to be shipped to an ISFS facility (18,000 MTU capacity) starting in the year 1983. Starting in the year 2010 and during the first four years of operation, the first disposition facility operates at partial capacity, and spent fuel is shipped to both the ISFS facility and to the disposition facility. In the year 2014, the disposition facility reaches full capacity operation, and spent fuel is then shipped directly from the reactor discharge basins to the disposition facility. Approximately 91,200 MTU of spent fuel is shipped to the ISFS facility between the years 1983 and 2013. Spent fuel movement and inventories for domestic spent fuel under Alternative 3A are given in Table E-1 for startup of the initial disposition facility in the year 2010.

Environmental effects of Alternative 3A with a 2010 startup of the initial disposition facility are determined for the following activities:

- Construction of government ISFS facilities from the year 1980 to 2011. ISFS facilities required (one 5000 MTU basin and five 18,000 MTU basins).

- Shipment of about 91,200 MTU of domestic spent fuel from reactor basins (1983-2013) and storage in the ISFS facility through the year 2031.

- Shipment to the disposition facility of about 23,800 MTU spent fuel from reactor basins (2010-2015) and about 91,200 MTU spent fuel from ISFS facilities (2014-2031). (The environmental effects of spent fuel shipped into the disposition facilities from the reactor after the year 2016 are not included.)

- Decommissioning of ISFS facilities (2022-2034).

E.2.1.2 Alternative 3B

In Alternative 3B (decentralized storage), irradiated domestic reactor fuel is retained in reactor storage basins consistent with

TABLE E-1

C Domestic Spent Fuel Shipments — Centralized Storage (Alternative 3A) or Decentralized Storage (Alternative 3B) — Policy Implemented and Decentralized Storage in Private ISFS Facilities (Alternative 4A) — Policy Not Implemented

Year	*ISFS Basins Fuel Shipments, MTU*	*ISFS Basin Inventory, MTU*	*Disposition Facility Fuel Shipments, MTU*		*Disposition Facility Inventory, MTU*
	Reactor to ISFS Basin		*Reactor to Disposition Facility*	*ISFS Basin to Disposition Facility*	
1983	400	400			
1984	200	600			
1985	200	800			
1986	300	1100			
1987	400	1500			
1988	500	2000			
1989	600	2600			
1990	700	3300			
1991	900	4200			
1992	1300	5500			
1993	1600	7100			
1994	1700	8800			
1995	2100	10900			
1996	2400	13300			
1997	2800	16100			
1998	3100	19200			
1999	3500	22700			
2000	3600	26300			
2001	4000	30300			
2002	4200	34500			
2003	4000	38500			
2004	6300	44800			
2005	4700	49500			
2006	5600	55100			
2007	5400	60500			
2008	7300	67800			
2009	4700	72500			
2010	6400	78900	100		100
2011	5100	84000	1600		1700
2012	5400	89400	1600		3300
2013	1800	91200	5200		8500
2014	0	90200	7500	1000	17000
2015		89400	7800	800	25600
2016		87600	8300	1800	35700
2017		86300	8900	1300	45900
2018		80200	9200	6100	61200
2019		71576	9700	8624	79524
2020		63011	10200	8565	98289
2021		54746	10500	8265	117054
2022		47081	11100	7665	135819
2023		39816	11500	7265	154584
2024		32951	11900	6865	173349
2025		26586	12400	6365	192114
2026		20621	12800	5965	210879
2027		15156	13300	5465	229644
2028		10091	13700	5065	248409
2029		5626	14200	4465	267074
2030		1500	14600	4126	285800
2031		0	15100	1500	302400

C maintaining reserve capacities equivalent to full-core discharge from the reactor. The initial disposition facility is assumed to become available in the year 2010 on the same basis as Alternative 3A. Spent domestic fuel movement and inventories for Alternative 3B are the same as Alternative 3A and are given in Table E-1.

Environmental effects under Alternative 3B (2010 startup of the initial disposition facility) are determined for the following activities:

- Construction of ISFS facilities (1980-2012). ISFS facilities required (sixteen 6000 MTU basins).
- Shipment of about 91,200 MTU spent fuel from reactor basins to ISFS facilities (1983-2013) and storage through the year 2031.
- Shipment to the disposition facility of about 23,800 MTU of domestic spent fuel from reactor basins (2010-2015) and about 91,200 MTU spent fuel from ISFS facility (2014-2031). (The environmental effects of spent fuel shipped into the disposition facilities from the reactors after the year 2016 are not included.)
- Decommissioning of ISFS facility (2019-2034).

E.2.2 Policy Not Implemented

Under the "Policy Not Implemented" alternative (Alternative 4), the U.S. Government is assumed to take no action to assist private industry in resolving uncertainties associated with the interim storage of spent nuclear fuel. Two options associated with Alternative 4 were examined under the scenario of a year 2010 startup date for the initial disposition facility. In option A (called Alternative 4A), decentralized storage is provided in small, private ISFS facilities (6000 MTU capacity) and in option B (called Alternative 4B), small stand-alone basins (500 to 2000 MTU capacity) are privately constructed at existing reactor sites for storage of spent fuel from the reactor discharge basins of nearby reactors until final disposition. These facilities are called at-reactor-basin (ARB) facilities.

E.2.2.1 Alternative 4A

Spent fuel movement and inventories for a year 2010 startup date of the disposition facility for Alternative 4A are given in Table E-1.

C The environmental effects for Alternative 4A with a year 2010 startup of the initial disposition facility are determined for the following activities:

- Construction of ISFS facilities (1980-2012). ISFS facilities required (sixteen 6000 MTU basins).
- Shipment of about 91,200 MTU spent fuel from reactor basins to ISFS facilities (1983-2013) and storage through the year 2031.
- Shipment to the disposition facility of about 23,800 MTU of domestic spent fuel from reactor basins (2010-2015) and about 91,200 MTU spent fuel from ISFS facilities (2014-2031).
- Decommissioning of ISFS facilities (2019 to 2034).

E.2.2.2 Alternative 4B

In Alternative 4B, new interim storage basins are assumed to be built by private industry on reactor sites, as needed. The earliest these ARBs could be supplied is assumed to be 1983. Spent fuel movement and inventories under Alternative 4B are given in Table E-2 for a year 2010 startup for the initial disposition facility.

Environmental affects of Alternative 4B with a year 2010 startup of the initial disposition facility are determined for the following activities:

- Construction of privately owned ARB storage facilities (starting in 1980). ARBs required (204 basins each with 500 MTU capacity, 53 basins each with 1000 MTU capacity, 10 basins each with 1500 MTU capacity, and 2 basins each with 2000 MTU capacity).
- Shipment of about 91,200 MTU of spent fuel from reactor discharge basins to ARBs (1983-2013) and storage in the ARBs through the year 2031.
- Shipment to the disposition facilities of about 23,800 MTU of spent fuel from reactor basins (2010-2015) and about 91,200 MTU of spent fuel from ARBs (2014-2031). (The environmental effects of spent fuel shipped into the disposition facilities from the reactors after the year 2015 are not included.)
- Decommissioning of ARBs (2022-2034).

TABLE E-2

C Domestic Spent Fuel Shipments — Decentralized Storage in At-Reactor Basins (Alternative 4B) — Policy Not Implemented

Year	*ARB Fuel Shipments, MTU*	*ARB Inventory, MTU*	*Disposition Facility Fuel Shipments, MTU*		*Disposition Facility Inventory, MTU*
	Reactor to ARB		*Reactor to Disposition Facility*	*ARB to Disposition Facility*	
1983	400	400			
1984	200	600			
1985	200	800			
1986	300	1100			
1987	400	1500			
1988	500	2000			
1989	600	2600			
1990	700	3300			
1991	900	4200			
1992	1300	5500			
1993	1600	7100			
1994	1700	8800			
1995	2100	10900			
1996	2400	13300			
1997	2800	16100			
1998	3100	19200			
1999	3500	22700			
2000	3600	26300			
2001	4000	30300			
2002	4200	34500			
2003	4000	38500			
2004	6300	44800			
2005	4700	49500			
2006	5600	55100			
2007	5400	60500			
2008	7300	67800			
2009	4700	72500			
2010	6400	78900	100		100
2011	5100	84000	1600		1700
2012	5400	89400	1600		3300
2013	1800	91200	5200		8500
2014		90200	7500	1000	17000
2015		89400	7800	800	25600
2016		87600	8300	1800	35700
2017		86300	8900	1300	45900
2018		80200	9200	6100	61200
2019		71300	9700	8900	79800
2020		62500	10200	8800	98800
2021		54000	10500	8500	117800
2022		46100	11100	7900	136800
2023		38600	11500	7500	155800
2024		31500	11900	7100	174800
2025		24900	12400	6600	193800
2026		18700	12800	6200	212800
2027		13000	13300	5700	231800
2028		7700	13700	5300	250800
2029		2900	14200	4800	269800
2030		0	14600	2900	287300
2031			15100	0	302400

C

E.3 Summary of Environmental Effects

The environmental effects of Alternatives 3 and 4 with delay of startup of the initial disposition facility until the year 2010 are assessed in this section. Radiological effects are evaluated for the operational period (years 1983 to 2031) and the next 100 years. Nonradiological effects are evaluated for the period of operation only. The radiation exposure to the public, occupational radiation doses, radiological health effects, and nonradiological deaths resulting from accidents are summarized in Table E-3.

The analysis shows there are no substantial environmental effects caused by radiation whether the policy is implemented or not. The total whole-body dose to the world population from handling, transporting, and storing spent fuel is higher for ARB facilities (85,000 man-rem) than for ISFS facilities (46,000 man-rem), but in either case, the doses are a very small fraction (less than 0.00003%) of the world population dose from natural radiation (about 4×10^{11} man-rem over the same period). The estimated occupational exposure ranges from 9600 man-rem to 92,000 man-rem. Again, the higher doses are for ARB facilities because a large number of facilities are operated. The number of radiological health effects on the world population over the operating period and the next 100 years from population and occupational exposures, estimated from EPA dose-effect factors, varies from 34 to 113 for these alternatives. Alternative 4B (ARB storage — policy not implemented) accounts for the highest number of health effects. Approximately half of the health effects for these alternatives are expected to occur in the population within 80 km (50 mi) of the ISFS or ARB facilities.

The estimated number of deaths in the construction and operating work force from nonradiological accidents for Alternatives 3A, 3B, and 4A are approximately the same (20 to 26). Accidental deaths for Alternative 4B (policy not implemented, decentralized storage in ARB facilities) are larger (112) than the other alternatives because of a larger work force. However, in all alternatives, the accidental deaths are a small fraction of the annual deaths from occupational accidents in the U.S. (12,500 in the year 1976).

In summary, the environmental impacts from all alternatives considered for a year 2010 startup of a disposition facility either from implementing or not implementing the Spent Fuel Policy are small. ARB storage increases environmental effects compared with those for ISFS facility storage because ARB facilities on the average have less efficient space utilization. However, the environmental impacts are relatively small compared with risks from natural radiation sources.

TABLE E-3

Summary of Environmental Effects

	Policy Implemented		*Policy Not Implemented*	
	Centralized Storage (Alternative 3A)	*Decentralized Storage (Alternative 3B)*	*Decentralized Storage (Alternative 4A)*	*Storage in ARBs (Alternative 4B)*
World Population, Whole Body Dose Commitment, man-rem	46,200	46,200	46,200	85,100
Occupational Exposure, man-rem	9,600	15,300	15,300	92,400
World Health Effects[a]	34	38	38	113
World Accidental Deaths	20	26	26	112

a. Serious genetic and somatic health effects were calculated from radiation doses, assuming a linear dose-health effect relation. EPA dose-effect factors were used. Health effects from organ doses are not shown independently, but these organ health effects are included in these lines along with those caused by the whole body dose. (See Appendix B of this volume for more detail on methodology used in determining health effects.)

C

E.4 Environmental Analysis

The major environmental effects presented in this section for Alternatives 3 and 4 (startup of the initial disposition facility in the year 2010) are population dose commitments, occupational exposures, radiological health effects, and deaths resulting from accidents. Other effects such as resources committed and the environmental impacts of nonradiological releases (e.g., thermal effluents, gaseous, liquid and chemical effluents, etc.) are not included in this appendix. These effects were assessed in the body of this volume where they were noted to be well within accepted limits for handling, transport, and storage of approximately 72,200 MTU of domestic spent fuel. The delay of the startup of the disposition facility until the year 2010 increases the amount of domestic spent fuel handled and stored and the nonradiological effects are proportionally greater but are still well within accepted limits. Likewise resource commitments and land requirements would be slightly greater and should vary proportionally to the facilities and transportation required. They would, however, represent a very small fraction of U. S. land and other resources.

E.4.1 Methodology

The methodology described in DOE-ET-0054[10] was used to calculate the population radiation dose, occupational radiation dose, radiological health effects, and fatalities resulting from operation of facilities for Alternatives 3 and 4, assuming start of a disposition facility in the year 2010. Assumptions for release of radionuclides, injury rate, demography, etc. were the same as those used in other places in this volume.

The radiological and other health effects caused by transportation of spent fuel and low level wastes for the ISFS facilities in this appendix are calculated with the methodology described in DOE-ET-0054[10] and in this volume. Also, the assumptions made in the remainder of this volume are used for Alternatives 3 and 4, except that the truck-rail transport ratio is changed for domestic spent fuel shipments after the year 2000. In other parts of this volume, the assumption was made that 30% by weight of the domestic spent fuel would be transported by truck and the rest by rail, based on estimates of reactors without rail facilities in the late 1980's. By the year 2000 about 90% of the commercial nuclear reactors are assumed to have rail facilities because new reactor facilities are assumed to include rail capability for transportation of spent fuel whenever possible. Therefore, for any spent fuel moved from reactors after the year 2000 a 10/90% truck/rail ratio is assumed to calculate the radiological effects of transportation.

C E.4.2 Environmental Effects

Population and occupational radiological dose commitments, radiological health effects, and accidental deaths are shown in this section for alternatives of Policy Implemented (Alternative 3) and Policy Not Implemented (Alternative 4) with startup of the initial disposition facility in the year 2010.

E.4.2.1 Population Dose Commitments

The world population dose commitments from handling, transporting, and storing domestic spent power reactor fuel for the alternatives assessed with startup of the initial disposition facility in the year 2010 range from 46,000 man-rem to 85,000 man-rem. The dose commitments are greatest for storage in ARB facilities when the policy is not implemented. These dose commitments are small when compared to the population dose commitment from natural radiation sources of 370,000,000,000 man-rem (or 3.7×10^{11}) to the same population over the same period.

The population within 80 km (50 mi) of the release site (called local population) receive approximately half of the total world population dose commitment. These dose commitments range from 24,000 to 46,000 man-rem for the four alternatives considered over the same time period. This dose commitment is about one tenth of a percent of the dose commitment this population group would receive from natural radiation sources (3.5×10^{7} man-rem).

E.4.2.1.1 Policy Implemented (Alternative 3)

For Alternative 3 the government provides large centralized storage facilities (Alternative 3A) or small decentralized storage facilities (Alternative 3B). The spent fuel flows are the same for these alternatives and are shown in Table E-1 in Section II of this appendix.

The population dose commitments for Alternatives 3A and 3B are essentially the same and are shown in Table E-4. The amount of fuel handled, storage capacities required as a function of time, effective age of fuel, storage times, and transportation activities are essentially the same for Alternatives 3A and 3B. The calculated whole body population dose commitment during 48 years of operations (and the persistent effects for the next 100 years) are 24,300 man-rem to the local population within 80 km (50 mi) of the release point, 20,200 man-rem to the U.S. population other than the local population, and 1640 man-rem to the world population (excluding the U.S. population).

C

TABLE E-4

Population Dose Commitment — Centralized Storage (Alternative 3A) or Decentralized Storage (Alternative 3B) — Policy Implemented

	Population Dose, man-rem[a]			
Organ	*Local, 80-km radius*	*U.S., Less Local*	*World, Less U.S.*	*Total*
Whole Body[b]				
Transportation - external gamma	18	155	-	173
Releases during cask venting	4	7	74(40)	85(51)
ISFS - Normal operations	24300	20000	1570(850)	45900(45200)
Total	24300	20200	1640(890)	46200(45400)
Thyroid[c]				
Releases during cask venting	187	159	-	346
ISFS - Normal operations	73	62	-	135
Total	260	220	-	480
Bone[c]				
Releases during cask venting	2	2	-	4
ISFS - Normal operations	3330	2630	-	5960
Total	3330	2630	-	5960
Lung[c]				
Releases during cask venting	<1	<1	66	66
ISFS - Normal operations	10	37	1400	1450
Total	10	37	1470	1520
Red Marrow[c]				
Releases during cask venting	<1	<1	52	52
ISFS - Normal operations	6	36	1550	1590
Total	6	36	1600	1640

a. Continued effects of releases included for a 100-year period after end of operation.

b. Gonad doses shown in parentheses when gonad doses differ from whole body doses.

c. Doses in addition to organ dose from whole body irradiation.

C E.4.2.1.2 Policy Not Implemented (Alternative 4)

For Alternative 4, Policy Not Implemented and initial disposition facility startup delayed until the year 2010, private industry is assumed to provide either decentralized ISFS facilities away from reactors (Alternative 4A) or interim storage facilities on existing reactor sites (Alternative 4B). Fuel flows, amount of interim storage capacity, and the environmental effects of Alternative 4A are the same as Alternative 3B for domestic spent fuel. The population dose commitment for Alternative 4A and Alternative 4B are shown in Table E-5.

The calculated doses are larger for Alternative 4B than for Alternatives 3A, 3B, and 4A. In Alternative 4B, the calculated doses are 46,300 man-rem to the local population (within 80 km of the release point), 37,100 man-rem to the U.S. population (less the local population), and 1640 man-rem to the non-U.S. world population.

E.4.2.2 Occupational Dose Commitments

The calculated occupational radiation doses during handling, transportation, and interim storage of spent fuel with the initial disposition facility startup in the year 2010 are summarized in Table E-6 for Alternatives 3A, 3B, 4A, and 4B. The total occupational doses during 48 years of operations range from 9600 man-rem for centralized storage with the policy implemented (Alternative 3A), to 92,400 man-rem for ARB interim storage (Alternative 4B). The occupational dose caused by the handling and storage per unit of spent fuel is an inverse function of basin size, i.e., the accumulated dose/MTU of spent fuel handled and stored is considerably greater at the small storage basins built at reactor sites than at a large centralized basin due to less efficient use of operating manpower at smaller facilities.

E.4.2.3 Radiological Health Effects

The radiological health effects estimated from the combination of population and occupational radiation doses accumulated during 48 years of operation and effects from released radionuclides for the next 100 years are summarized in Table E-7 for Alternatives 3A, 3B, 4A, and 4B. The calculated radiological health effects range from 35 for large centralized storage basins to 113 health effects for smaller ARBs. For comparison, the calculated health effects from natural radiation sources are 200,000,000 (or 2×10^8) in the world population during the same time period considered for these alternatives.

TABLE E-5

Population Dose Commitment — Decentralized Storage in Private ISFS Facilities (Alternative 4A) and At-Reactor Storage (Alternative 4B) — Policy Not Implemented

	Population Dose, man-rem[a]							
	Private ISFS Facilities (Alternative 4A)				*At-Reactor Basins (Alternative 4B)*			
Organ	*Local, 80-km radius*	*U.S., Less Local*	*World, Less U.S.*	*Total*	*Local, 80-km radius*	*U.S., Less Local*	*World, Less U.S.*	*Total*
Whole Body[b]								
Transportation - external gamma	18	155	-	173	10	96	-	106
Releases during cask venting.	4	7	74(40)	85(51)	4	7(6)	74(40)	85(50)
ISFS - Normal operations[c]	24300	20000	1570(850)	45900(46200)	46300	37000(36900)	1570(850)	84900(84100)
Total	24300	20200	1640(890)	46200(45400)	46300	37100(37000)	1640(890)	85100(84300)
Thyroid[d]								
Releases during cask venting	187	159	-	346	19	159	-	178
ISFS - Normal operations[c]	73	62	-	140	73	62	-	135
Total	260	220	-	480	90	220	-	310
Bone[d]								
Releases during cask venting	2	2	-	4	2	2	-	4
ISFS - Normal operations[c]	3330	2630	-	5960	5660	4450	-	10100
Total	3330	2630	-	5960	5660	4450	-	10100
Lung[d]								
Releases during cask venting	<1	<1	66	66	<1	<1	66	66
ISFS - Normal operations[c]	10	37	1400	1450	10	37	1400	1450
Total	10	37	1470	1520	10	37	1470	1520
Red Marrow[d]								
Releases during cask venting	<1	<1	52	52	<1	2	73	75
ISFS - Normal operations[c]	6	36	1550	1590	6	36	1550	1590
Total	6	36	1600	1640	6	38	1620	1670

a. Continued effects of releases included for a 100-year period after end of operations.

b. Gonad doses shown in parentheses when gonad doses differ from whole body doses.

c. At-Reactor Basins (ARBs) used in Alternative 4B.

d. Doses in addition to organ dose from whole body irradiation.

C TABLE E-6

Occupational Doses, man-rem

	Transportation	*ISFS or ARB Facilities*	*Total*
Policy Implemented			
Centralized Storage (Alternative 3A)	480	9110	9590
Decentralized Storage (Alternative 3B)	480	14,800	15,280
Policy Not Implemented			
Decentralized Storage Utility-Owned ISFS (Alternative 4A)	480	14,800	15,280
Decentralized Storage Utility-Owned ARBs (Alternative 4B)	270	92,100	92,370

C TABLE E-7

Total Calculated Health Effects[a]

	Population	*Occupational*	*Total*
Policy Implemented			
Centralized Storage (Alternative 3A)	27.9	6.4	34.3
Decentralized Storage (Alternative 3B)	27.9	10.2	38.1
Policy Not Implemented			
Decentralized Storage Utility-Owned ISFS (Alternative 4A)	27.9	10.2	38.1
Decentralized Storage Utility-Owned ARBs (Alternative 4B)	51.4	61.9	113

a. Serious genetic and somatic health effects were calculated from radiation doses, assuming linear dose-health effect relation. EPA dose-effect factors were used. Health effects from organ doses are not shown independently, but these organ health effects are included along with those caused by the whole body dose. (See Appendix B of this volume for more detail on methodology used in determining health effects.)

C E.4.2.4 Accidental Deaths

The estimated occupational accidental deaths from construction of storage facilities and then the handling, storage, and transportation of spent fuel are shown in Table E-8 for Alternatives 3A, 3B, 4A, and 4B. Accidental deaths are expected to range from 20 for large storage facilities (Alternative 3A) to 112 for the smaller ARBs (Alternative 4B) and are a function of the number of storage facilities constructed and operated over the operating period of 48 years. For comparison, 12,500 deaths were reported for occupational accidents in the U.S. alone during the year 1976 or 600,000 (6×10^5) occupational deaths can be predicted to occur in the U.S. during the 48-year period. The accidental deaths per unit of spent fuel handled and stored are greater for construction and operation of small facilities than for a few large facilities. The slight decrease in expected transportation deaths due to the lower transportation in Alternative 4B is overshadowed by the large increase in ARB facility deaths.

TABLE E-8

Occupational Accidental Deaths

	Transportation	*ISFS or ARB Facilities*	*Total*
Policy Implemented			
Centralized Storage (Alternative 3A)	8.9	11.0	19.9
Decentralized Storage (Alternative 3B)	8.9	16.6	25.5
Policy Not Implemented			
Decentralized Storage Utility-Owned ISFS (Alternative 4A)	8.9	16.6	25.5
Decentralized Storage Utility-Owned ARBs (Alternative 4B)	7.6	104	112

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APPENDIX F

GLOSSARY OF TERMS AND ABBREVIATIONS

actinide

The series of elements beginning with actinium, atomic number 89, and continuing through lawrencium, atomic number 103.

activation

The process of making a material radioactive by absorption of neutrons, protons, or other nuclear particles.

activation product

A nuclide formed by activation.

activity

Radioactivity or radioactive materials. A measure of the rate at which a material is emitting radiations; usually given in terms of the number of nuclear disintegrations occuring in a given quantity of material over a unit of time. The standard unit of activity is the curie (Ci).

AEC

Atomic Energy Commission (discontinued with formation of ERDA and NRC on January 19, 1975).

C AFR

An acronym for Away-From-Reactor. Sometimes used as AFR basins or facility.

aging

Holding radioactive fuel and wastes while short-lived radionuclides decay.

alpha emitter

A nuclide which undergoes radioactive decay by emitting an alpha particle, a positively charged particle.

aquifer

A water-bearing layer of permeable rock or soil.

ARB

At-reactor basin. A facility constructed adjacent to reactors to provide interim storage of spent fuel to minimize risks to the public associated with transportation.

background dose

The levels of ionizing radiation received in man's natural environment, including cosmic rays and radiation from naturally occurring radioactive elements. Background doses within the U.S. vary by a factor of about two, depending upon the location.

biosphere

The part of the world in which life can exist, including the lithosphere, hydrosphere, and atmosphere; living beings together with their environment.

biota

The animal and plant life of a region.

burial ground

A land area specifically designated for storage or disposal of containers of low-level radioactive solid wastes and obsolete or worn out equipment in shallow land burial.

BWR

Boiling water reactor is a nuclear reactor in which boiling light water is used as the coolant.

canister

A metal container for radioactive solid waste.

cask

A container that provides shielding and containment for the shipment or storage of radioactive material.

C Category 1 Structure

A structure designed to withstand maximum credible disasters, such as earthquakes and tornadoes.

cc

Cubic centimeters.

cfm

Cubic feet per minute.

CFR

U.S. Code of Federal Regulations, subdivided by Titles and Parts, available from U.S. Government Printing Office, Washington, DC.

C 10-CFR-100 (also 10 CFR Part 100 or U.S. Code of Federal Regulations, Title 10, Part 100)

U.S. Code of Federal Regulations Title 10. Part 100, "Reactor Site Criteria."

cfs

Cubic feet per second.

Ci

C Curie(s). (see "Curie.")

cladding

The outer jacket of a nuclear fuel or target element.

compaction

Reduction in the spacing of racks that hold spent fuel in a water storage basin so that the basin can hold more fuel and still remain subcritical.

Concentration Guide (CG)

The average concentration of a radionuclide in air or water to which a worker or member of the general population may be continuously exposed without exceeding radiation dose standards as
C specified in 10-CFR-20, "Standards for Protection Against Radiation."

contamination

The deposition of radioactive material on a surface or the presence of fission products in a process stream.

criticality

State of being critical: a self-sustaining neutron chain reaction in which there is an exact balance between the production and loss of neutrons.

curie

The basic unit used to describe the intensity of radioactivity in a sample of material. One curie (Ci) equals 37 billion disintegrations per second.

CW

Cooling Water.

dbA

"decibels Audio," a unit for measuring noise levels upon which occupational standards are based.

DBE

Design Basis Earthquake. An earthquake, that is postulated to be the most severe near any site. The DBE is based upon historical records, and is used as a basis for facility and system design.

decay (radioactive)

The spontaneous transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide.

decommissioning

The management or disposition of worn out or obsolete nuclear facilities or contaminated sites. Decommissioning operations remove facilities such as reprocessing plants and ISFS Basins from service and reduce or stabilize radioactive contamination.

decontamination

The selective removal of radioactive material from a surface or from within another material.

deionizer

A metal vessel containing ion exchange resins, used for removing positively or negatively charged ions from water.

densification

See "compaction."

depleted uranium

Uranium having a percentage of uranium-235 smaller than the 0.7% found in natural uranium.

DF

An acronym for Decontamination Factor. The ratio of the concentration of a fission product in the feed stream to that of the treated effluent.

diffusion climatology

Use of average local meteorological parameters to predict atmospheric concentrations of releases of material from a specified source.

discharge capability

C Reserve storage capacity maintained in the reactor discharge basin to accommodate the scheduled annual discharge of fuel (from 1/4 to 1/3 of the core load).

disintegration

(Radioactive decay) - the spontaneous transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide. The process results in emission of energy and/or mass from the nucleus.

disposal

The planned release of radioactive and other waste in a manner that precludes recovery, or its placement in a manner which is considered permanent so that recovery is not provided for.

disposition facility

An undefined generic facility assumed, in this volume, to receive spent fuel from reactor and ISFS basins at some point in the schedule.

disposition mode

The mode of disposing of spent fuel in this volume. It could consist of either permanent disposal in a geological repository or fuel reprocessing.

DOE

Department of Energy (created October 1, 1977). Includes former Energy Research and Development Administration.

dose

The amount of absorbed energy imparted to matter, when ionizing radiation passes through that matter, per unit mass of the irradiated material.

dose commitment

The amount of radiation to an individual or population over a stipulated period of time resulting from exposure to a given source.

DOT

Department of Transportation

enriched uranium

Uranium in which the percentage of the fissionable isotope uranium-235 has been increased above the 0.7% normally found in natural uranium.

EPA

Environmental Protection Agency.

ERDA

Energy Research and Development Administration (includes part of the former AEC). Discontinued with formation of the Department of Energy (DOE) in 1977.

ERDAM

ERDA Manual (for ERDA operations and ERDA contractors).

Federal repository

A U.S. Government-controlled facility to be used for the disposal of nuclear waste.

feral

C | Wild, or having reverted to the wild state, applied to animals.

fertile material

A material, for example uranium-238, not itself a readily fissionable material, which can be converted into a fissionable material (plutonium-239) by irradiation in a reactor.

fission (nuclear)

The spontaneous or neutron induced splitting of a heavy nucleus into two nuclei or more of different mass, with the emission of 2 or more neutrons and substantial energy.

fission product

A nuclide produced by fission or from radioactive decay of the nuclide thus formed.

fissionable material

Any material that fissions from neutron absorption.

fly ash

Airborne ash from fuel burning operations.

food chain

A linear sequence of successive utilizations of nutrient energy by a series of plant and animal species.

FRC

Federal Radiation Council (now part of EPA).

frequency

The number of times an event can be postulated to occur, or actually occurs per unit of time.

C fuel (Nuclear reactor)

Fissionable material used as the source of energy when placed in a nuclear reactor.

fuel assembly

A grouping of fuel elements which is not taken apart during the charging and discharging of a reactor core.

fuel cycle

The complete series of steps involved in supplying fuel for nuclear reactors. The cycle includes uanium mining and refining, uranium enrichment, fuel element fabrication, irradiation, chemical reprocessing (to recover the fissionable material remaining in the spent fuel), and disposal of radioactive waste. Later steps in the fuel cycle are re-enrichment of the enriched fuel material and refabrication into new fuel elements. In a "stowaway" fuel cycle, spent fuel is not reprocessed to recover usable fuel; spent fuel is treated as waste.

fuel element

The smallest structurally discrete part of a reactor assembly which has nuclear fuel as its principal constituent.

full-core reserve

Reserve storage capacity maintained in the reactor discharge basin to accommodate all of the spent fuel contained in the reactor.

full-cost recovery

Includes charges to the user that compensate the government for budgetary spending, for capital and operating costs, for return on invested capital, and for costs to cover unusual hazards, e.g., insurance premiums, premium pay for hazardous work, workmen's compensation, etc.

g

grams.

gal

gallons.

gamma rays (γ)

High-energy, short-wavelength electromagnetic radiation emitted by a nucleus. Gamma radiation accompanies radioactive decay, neutron capture, and fission.

GAO

General Accounting Office (under the Comptroller General of the United States).

geologic storage

Storage in a repository constructed in a geologic formation.

g/L

grams per liter.

gpm

gallons per minute.

groundwater

Water that exists or flows in the zone of saturation beneath the land surfaces.

GWe

Gigawatts electric, i.e., one billion (10^9) watts or one-thousand megawatts.

half-life

The time in which half the atoms in a radioactive substance spontaneously disintegrate to another nuclear form.

7-f health effect

As used in this environmental impact statement, a health effect from exposure to ionizing radiation may be a somatic effect (malignancies) and/or genetic effect. Somatic and genetic effects are summed to show total health effects.

health physics

The science and profession devoted to the protection of man and his environment from unnecessary exposure to ionizing radiation.

heavy metals

All the chemical elements with atomic numbers of 81 or greater, beginning with thallium.

heavy water

Deuterium oxide, D_2O. Water in which hydrogen atoms have been replaced with deuterium atoms.

high-efficiency particulate air (HEPA) filter

An air filter designed to achieve 99.97 percent minimum efficiency in the containment of airborne radioactive particulates of greater than 0.3 micron size.

high-level waste

High-level liquid waste, or products from solidification of high-level liquid waste obtained from chemical processing of irradiated fuel, and/or irradiated fuel elements if discarded without processing.

high-level liquid waste

The aqueous waste resulting from the operation of head-end and first-cycle extraction (or equivalent waste from a process not using solvent extraction) in a facility for processing irradiated reactor fuels.

ICRP

International Commission on Radiological Protection

interim storage

Storage operations for which surveillance and human control are provided and for which subsequent action involving treatment, transportation, or fuel disposition is expected.

ion

An atom with an electrical charge from either the loss or gain of an electron.

ion exchange

A reversible transfer between ions in solution and different ions contained in or on a crystal or resin without destruction of the crystal.

ISFS

Independent Spent Fuel Storage (away-from reactor)

isotope

Any of the two or more forms of the same element, containing the same number of protons but different number of neutrons. The isotopes are chemically similar but have different atomic weights.

kilo

A prefix indicating one thousand (10^3) times the affixed unit, abbreviated "k."

km

kilometers (1 kilometer = 1000 meters or 0.621 mile).

kWh

kilowatt-hour, a unit of energy generation or consumption in a given hour.

kW-yr

kilowatt-year, a unit of energy generation or consumption in a given year.

lattice

The geometric arrangement of fuel assemblies.

light water

Normal water (H_2O), as distinguished from heavy water (D_2O).

light water reactor (LWR)

Uses light water (H_2O) as coolant and as the moderator for slowing fast neutrons. Most common types are pressurized water reactors (PWR) or boiling water reactors (BWR).

long-term storage

The status of radioactive waste under control and surveillance, and readily retrievable, but in such a form and location that no further processing or manipulation is considered necessary for a period of time in the nuclear fuel cycle; an example would be storage in a high-quality near-surface storage vault with an expected durability of many decades.

LWT

Abbreviation for legal-weight truck.

m

(1) meter; (2) as prefix, milli. See "milli."

man-rem

The total radiation dose commitment to a given population group; the sum of the individual doses received by a population segment.

maximum permissible concentration (MPC)

The quantity of radioactive material in air, water, etc., per unit volume or weight, from which a human, if continuously exposed,
C should not sustain appreciable body damage. (See "Concentration Guide".)

minimum critical mass

The minimum mass of fissionable material that, with a specified geometrical arrangement and material composition, will self-sustain a fission chain reaction.

meteorology

The science concerned with the atmosphere and its phenomena, especially as related to the weather.

metric ton (MT)

Unit of weight; 1 MT = 1000 killograms.

mg

milligrams.

micro (μ)

Prefix indicating one millionth (1 microgram = 1/1,000,000 of a gram or 10^{-6} gram).

milli

Prefix indicating one-thousandth (1 milli = 1/1000 of a rem or 10^{-3} rem).

millirem

One-thousandth of a rem.

mL

milliliters.

MM

Modified Mercalli (scale of earthquake intensities).

MW

Megawatt (1 MW - 1 million watts), a unit of the rate of energy production or consumption.

MW-yr

Megawatt-year. A unit of energy generation or consumption in a given year.

moderator

A material, such as water or graphite, used in a reactor to slow down high-velocity fission neutrons.

mph

miles per hour.

mrem

millirems.

MTU

Metric Tons of Uranium, (2200 pounds, or 1000 kilograms).

nano

A prefix indicating 10^{-9} times the affixed unit, abbreviated "n."

natural uranium

Uranium as found in nature. It is a mixture of the fertile uranium-238 isotope (99.3%), the fissionable uranium-235 isotope
E (0.7%), and a minute percentage of uranium-234.

nCi

nanocuries.

NCRP

National Council on Radiation Protection and Measurements.

neutron

An uncharged elementary particle with a mass nearly equal to that of the proton. Neutrons sustain the fission chain reaction in a nuclear reactor.

noble gas

A chemically inert gas, e.g., xenon, argon, and krypton.

nonproliferation

Limits the number of nations capable of producing nuclear weapons without limiting worldwide use of nuclear power.

NO_x

An acronym for a mixture of nitrogen oxides in no particular ratio or quantity.

NRC

Nuclear Regulatory Commission (includes the regulatory branch of the former AEC).

nuclear reaction

Neutron reactions with materials that cause fission or transmutation with the simultaneous release of energy.

nuclear safety

The application of technical knowledge and administration control to prevent an unplanned, uncontrolled nuclear chain reaction.

nucleus

The positively charged center of an atom.

nuclide

A species of atom characterized by its mass number, atomic number, and nuclear energy state, provided that mean life in that state is long enough to be observable.

NWTS

National Waste Terminal Storage.

off-gas

Gas released by any process in the fuel cycle.

order of magnitude

A factor of 10.

OSHA

Occupational Safety and Health Act of 1970.

overpack

Secondary (or additional) external containment for packaged nuclear waste.

parapet level

The railing and walkway area directly over the water surface of the spent fuel storage basin.

C | parent (nuclear)

A precursor radionuclide that upon disintegration yields a specified nuclide, the daughter, either directly or as a later member of a radioactive series.

pCi

pico-curies.

perched water

Groundwater separated from the water table by unsaturated rock or soil.

pico

Prefix indicating one-millionth of a micro unit (1 picocurie = 1/1,000,000 of a microcurie or 10^{-12} curie).

plenum

An enclosure in which a fluid is at a pressure higher than that outside the enclosure.

plutonium

A radioactive element with an atomic number of 94. Its most important isotope is fissionable plutonium-239, produced by neutron irradiation of uranium-238.

pool or pool cell

A concrete chamber filled with water to provide shielding for irradiated fuel elements.

population dose

The summation of radiation exposures received by the member of a population group over a given time period.

ppb

parts per billion.

ppm

parts per million.

probability

The chance of an event occurring in a unit time, usually expressed as events per year.

rad

Radiation absorbed dose. The basic unit of absorbed dose of ionizing radiation. One rad is equal to the absorption of 100 ergs of radiation energy per gram of matter.

radioactive

Unstable in a manner shown by spontaneous nuclear disintegration with accompanying emission of radiation and particles.

radioactive decay

The spontaneous decrease of a radioactive substance due to disintegration by the emission of particles and radiation.

radioactivity

The spontaneous decay or disintegration of unstable nuclei accompanied by the emission of radiation and particles.

radioisotope

An isotope of an element which decays radioactively.

radionuclide

An unstable nuclide that decays radioactively.

radwaste

Waste containing radioactive contamination.

RBOF

Receiving Basin for Offsite Fuels, a facility at the DOE's Savannah River Plant.

C reactor (Nuclear)

A device in which a fission chain reaction can be initiated, maintained, and controlled.

rem

A unit used in radiation protection to express the effective dose equivalent for all forms of ionizing radiation. It is the product
C of the absorbed dose in rads and quality and modifying factors.

repository

A facility or designated site for storage or disposal of high-level and TRU radioactive wastes.

reprocessing

Dissolving spent reactor fuel to recover useful materials such as thorium, uranium, and plutonium. Other radioactive materials are usually separated and treated as waste.

resin

A synthetic organic-polymer that can act as an ion exchanger.

retrievability

Capability to recover waste from interim storage.

risk

The product of an event's frequency and its consequence yielding an estimate of the expected damage rate (e.g., population dose per year) from a specified event.

risk assessment

The evaluation and comparison of several independent or associated risks.

roentgen

A unit of exposure dose of ionizing radiation. It is that amount of gamma or x-rays required to produce ions carrying one electrostatic unit of electrical charge in one cubic centimeter of dry air under standard conditions.

seismicity

The tendency for the occurrence of earthquakes.

separations

Chemical processes used to separate nuclear products from each other.

shielding

The material interposed between a source of radiation and the environment for protection against the danger of radiation. Common shielding materials are concrete, water, and lead.

shipping cask

A specially designed container used for shipping radioactive materials (see cask).

smear

(Swipe) - to wipe a surface with cloth or paper to determine if any loose (smearable) contamination is present.

special nuclear materials

Materials that could be used to make nuclear weapons if they were available in sufficient quantity and purity.

spent fuel

Irradiated nuclear reactor fuel at the end of its useful life.

SSC

Sealed storage cask.

storage

Retention of waste in some type of man-made device.

storage basin

A water-filled, stainless steel-lined pool for the interim storage of spent fuel.

sump

Any low area that receives and contains drainage.

tectonic

Pertaining to structural deformation of the earth's crust.

ton

C | Unit of weight, 1 ton = 2000 pounds (1 short ton).

tonne

C | Unit of weight, 1 tonne = 1000 kg (1 metric ton).

transmutation

A change of one element into another.

transuranium elements

Elements above uranium in the periodic table, that is, with an atomic number greater than 92. All 13 known transuranium elements are radioactive. Examples are neptunium, plutonium, curium, californium.

transuranic waste

Any solid waste material measured or assumed to contain transuranic elements in excess of 10 nCi/g.

tritium

A radioactive isotope of hydrogen containing two neutrons and one proton in the nucleus, with an atomic weight of 3. It is heavier than deuterium (heavy hydrogen) with an atomic weight of 2.

TRU

Transuranic.

unstable

Chemical: compounds which readily decompose or change into other compounds.
Radioactive: nuclides which decay to form other nuclides and emit radiation in the process.

uranium

A naturally radioactive element with the atomic number 92 and an atomic weight of approximately 238. The two principal naturally occurring isotopes are the fissionable uranium-235 (0.7% of natural uranium) and the fertile uranium-238 (99.3% of natural uranium).

USAEC

United States Atomic Energy Commission (see AEC).

C USDOE

United States Department of Energy (See DOE).

USGS

United States Geological Survey.

C USNRC

United States Nuclear Regulatory Commission (see NRC).

waste immobilization

Process of converting waste to a stable, solid form which ties up the radionuclides thereby preventing (or slowing) their migration to the biosphere.

waste management

The planning, execution, and surveillance of essential functions related to the control of radioactive (and nonradioactive) waste, including treatment, solidification, initial or long-term storage, surveillance, and disposal.

waste, radioactive

Equipment and materials (from nuclear operations) that are radioactive or have radioactive contamination and for which there is no recognized use or for which recovery is impractical.

water table

Upper boundary of an unconfined aquifer below which saturated groundwater occurs; defined by the levels at which water stands in wells that barely penetrate the aquifer; the water surface in an unconfined aquifer at which the pressure is atmospheric.

zeolite

Any of various hydrous silicate that can act as ion exchangers.

μ

Prefix indicating one millionth. Same as "micro."

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