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REVISED

FINAL
ENVIRONMENTAL IMPACT STATEMENT
U. S. SPENT FUEL POLICY

Storage of Foreign Spent Power Reactor Fuel

APRIL 1980

U. S. DEPARTMENT OF ENERGY

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Washington, DC 20545

FOREWORD

Spent fuel removed from a nuclear power reactor contains unfissioned nuclear fuel, together with radioactive waste fission products. On April 7, 1977, President Carter announced that the U.S. would indefinitely defer reprocessing of spent fuel for recovery of the unfissioned fuel so the U.S. and other countries could evaluate alternative fuel cycles and processes which might reduce risks of nuclear weapons proliferation. Eventually, the spent fuel will either be declared to be entirely waste; and provision will be 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.

In October 1977, a Presidential policy on the interim management of spent fuel was announced. 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 addition, under this policy, the Federal Government would offer to take title to and to accept a limited amount of spent fuel from foreign sources when such action would contribute to meeting nonproliferation goals. In December 1978, a draft environmental statement (DOE/EIS-0040-D) was issued to provide environmental input into decisions on whether, and if so, how this foreign spent fuel storage policy should be implemented. A notice of availability of the document was published in the Federal Register on December 14, 1979, and public comments were solicited.

A total of 78 comment letters (some with supplements) were received on the draft environmental statement and its companion draft documents on storage of U.S. spent fuel (DOE/EIS-0015-D) and on establishing the charge for spent fuel storage (DOE/EIS-0041-D). Major comments from these letters were categorized and are published in Volume 5 of this final EIS.

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:

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

C Changes from the draft statements are identified by vertical lines in the left margins 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 Statements and Major Comments With DOE Responses. If the change is the result of an error, it is identified with the letter "E," and if a change was made to clarify or expand on the draft statement, it is identified with the letter "C."

This volume of the final environmental impact statement is intended to provide environmental input into decisions regarding the portion of the spent fuel storage policy involving foreign spent fuel and focuses on the incremental effects of acceptance of foreign fuel in the U.S.

1-b If a decision is made to implement the Spent Fuel Policy,
1-c an away-from-reactor spent fuel storage facilities EIS (AFR-EIS) will be prepared to provide the environmental input needed for the selection of facilities required for domestic and foreign spent fuel storage. The demand for spent fuel storage will be developed by using the latest available data as supplied by domestic and foreign 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 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 NRC. The NRC licensing process will provide additional public input.

12-d If the Spent Fuel Storage Policy is implemented to include foreign spent fuel, a generic plan will be prepared as required by the Nuclear Non-Proliferation Act of 1978 and the DOE Authorization Act of 1978, Section 107. This generic plan is required before DOE can receive spent fuel from foreign countries for U.S. storage.

Possible approaches that the Federal Government could adopt
C for foreign spent fuel storage include: 1) acceptance of foreign spent fuel at either domestic centralized or decentralized storage basin(s), 2) encouragement of continued storage at foreign multinational or national basins, and 3) no new policy initiatives in this area.

It is proposed that the decision to accept spent fuel from a given country be made on a case-by-case basis, measured against one or both of the following criteria:

- The country is located in sensitive regions in which the storage of spent fuel would contribute to international tension.

- The acceptance of the spent fuel would lead to significant gains in nonproliferation (e.g., by encouraging alternatives to developing a national reprocessing capacity to meet spent fuel disposal needs, by stimulating implementation of desirable regional or international fuel cycle approaches consistent with overall U.S. policy, or by inducing adherence to the Treaty for the Nonproliferation of Nuclear Weapons, or other similar steps).

1-a DOE's preferred alternative is Case G; i.e., spent fuel from Option 2 (mid-range) countries is shipped to the U.S. for storage in ISFS facilities. The fuel covered by the United States under this policy would be selected to provide a nonproliferation benefit, as described above. It is assumed for purposes of analysis that this foreign fuel will eventually be disposed of as waste in a U.S. geologic repository. It should be noted, however, that DOE is not making a choice between reprocessing and disposal of spent fuel as waste at this time. DOE intends also to continue to support multinational storage, not by subsidies, but by discussion with foreign nations.

12-g 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 Environmental 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

12-g be modified and used to store spent fuel have been identified in Spent Fuel Program Preliminary Technical Assessment of Existing Facilities for AFR Storage Capability, DOE/SR/10007-1-Rev 1 (September 1979).

The alternatives for ultimate disposition of the spent fuel are discussed in this report to furnish the decisionmaker with an understanding of the possible long-term implications of the U.S. policy for accepting foreign spent fuel. They do not constitute
C a part of the policy at this time. Delays in the opening of the first geologic repository beyond the time frame originally analyzed in the draft EISs is a possibility. Between the time the draft EISs 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 1990's. As a result, DOE decided to prepare an appendix (Appendix A) to this volume to show the environmental effects associated with the interim storage of foreign reactor fuel in ISFS facilities with the first disposition facility startup in the year 2010. Appendix A compares the effects of the delay in startup of the geologic repository if the U.S. Spent Fuel Storage Policy is implemented or is not implemented.

A detailed analysis of the environmental impacts associated with the potential disposal of foreign spent fuel which may be
6-a shipped to the U.S. is contained in the Draft Environmental Impact Statement — Management of Commercially Generated Radioactive Waste (DOE/EIS-0046-D) which was recently issued. Other related environmental reviews which provided input to this EIS include: Light Water Reactor Fuel Reprocessing and Recycling (ERDA-77-75) and Final Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel (NUREG-0575).

The support document, Analytical Methodology and Facility and Environmental Description — Spent Fuel Policy (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 Appendix B.

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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 will 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.
1-f Government-approved site. Foreign spent fuel would be stored in ISFS facilities with domestic fuel.

C 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 would be 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.

This volume of the environmental impact statement includes
C effects associated with implementing or not implementing the Spent Fuel Storage Policy for the foreign fuels. To show the environmental impact of the foreign spent fuel that may be involved under the Spent Fuel Storage Policy, the incremental environmental effects associated with only the foreign fuel that may be accepted
C by the U.S. Government are assessed. This is the equivalent of the environmental impacts of implementing the foreign portion of the policy. The impact of the policy for the domestic fuels is reviewed in Volume 2 of this EIS. The major environmental effects of implementing both the domestic and foreign portions of the policy are analyzed in Sections G and H of Volume 1 of this EIS. 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.

The Spent Fuel Storage Policy is based upon the principle that the U.S. national interest will be served by encouraging delay of conventional reprocessing by other nations until more proliferation-resistant technologies and/or institutional arrangements can be developed. The U.S. offer to accept limited quantities of foreign spent power reactor fuel for storage in this country and the proposed program for storing spent fuel from domestic utilities can contribute to this and other nonproliferation objectives. Storage in the U.S. provides an option other than reprocessing to nations that have no alternative acceptable from a nonproliferation point of view for disposing of their spent fuel. If the foreign nations accept this offer, time would then be available for these nations to develop local storage capability or to investigate regional, multinational, or international storage facilities. The nations would then have time to evaluate and develop more proliferation-resistant technologies and/or institutional arrangements for their nuclear fuel cycles. If nations accept the U.S. offer, then such actions may assist in promoting an international consensus, favoring an evolutionary approach to the nuclear fuel cycle.

The environmental impacts of a full range of U.S. options associated with implementing the policy are evaluated and compared with the alternative of not implementing the policy. Basically, the U.S. offer to store foreign spent fuel involves a tradeoff between the potential gains for the nonproliferation policy and the additional risks to the environment posed by the transportation and storage of foreign fuel within the U.S. The analyses show that there are no substantial radiological health impacts whether the policy is implemented or not. In no case considered does the population dose commitment exceed 0.000006% of the world population dose commitment from natural radiation sources over the period analyzed.

Full implementation of the U.S. offer to accept a limited amount of foreign spent fuel for storage provides the greatest benefits for U.S. nonproliferation policy. Acceptance of lesser quantities of foreign spent fuel in the U.S. or less U.S. support of foreign spent fuel storage abroad provides some nonproliferation benefits, but at a significantly lower level than full implementation of the offer. Not implementing the policy in regard to foreign spent fuel will be least productive in the context of U.S. nonproliferation objectives.

The remainder of the summary provides a brief description of the options that are evaluated, the facilities involved in these options, and the environmental impacts, including nonproliferation considerations, associated with each option.

Eleven cases spanning the range of options associated with implementing and not implementing the U.S. offer to accept the foreign spent fuel are analyzed. In Cases A and J, the alternative of not implementing the Spent Fuel Storage Policy, the U.S. Government

C would take no action with respect to the storage of foreign spent fuel. The alternative of implementing the policy considers two major subalternatives.

1. U.S. Government accepts no spent fuel from foreign governments but provides assistance to foreign countries for storage of their spent fuel abroad. This is described in Cases B and C.
2. U.S. Government accepts foreign spent fuel for interim storage. The remaining seven cases (D through I) consider a range of possibilities under this subalternative. The amount of fuel accepted by the U.S. is projected and analyzed for three acceptance options.

Two basic disposition scenarios that have also been analyzed are disposal in U.S. or reprocessing in the U.S. or abroad. To maximize the impacts of the range of disposition modes, each mode was analyzed assuming the maximum fuel accepted.

Two parameters, the quantity of foreign fuel assumed to be shipped to the U.S. and the startup date of the U.S. geologic repository, are varied to show the environmental effects of the possible range of options associated with the implementation of the policy. These are briefly described below.

- Foreign Fuel Schedules. Three foreign fuel schedules are assumed in this environmental statement to show the range of foreign fuel that may reasonably be expected to be accepted by the U.S. Government under the policy. In each instance, acceptance of fuel would be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis. The amount of foreign fuel accepted by the U.S. under any of the fuel schedules would not exceed 19% of the spent fuel from U.S. power reactors that is received by the U.S. Government.

C In the Option 1 foreign spent fuel schedule, only fuel from countries in sensitive regions is considered. A total of about 2160 MTU (metric tons of uranium) of spent fuel is assumed.

In the Option 2 foreign spent fuel schedule, the Option 1 fuel level plus a very limited amount of spent fuel from a small number of other countries with spent fuel storage problems is considered when, from a nonproliferation standpoint, there may be benefits derived from U.S. acceptance of spent fuel from these additional countries. A total of about 4350 MTU is assumed.

In the Option 3 foreign spent fuel schedule, Option 2 fuel level, plus spent fuel from a few larger, industrialized non-nuclear weapons states, is considered on the same basis as Option 2. A total of about 13,600 MTU is assumed.

- Initial Operation of U.S. Geologic Repository. The environmental effects for the six cases that involve shipment of foreign spent fuel to the U.S. are evaluated, assuming the U.S. Geologic repository begins initial operation in the year 1985. The report to the President by the Interagency Review Group on Nuclear Waste Management[1] indicates that initial operation of the first geologic repository for high-level waste (spent fuel or reprocessing waste) is expected
6-b between the years 1988 and 1995. The IRG Report[2] 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." To identify the environmental effects associated with a delay in startup of the geologic repository, the cases that include shipment of foreign spent fuel to the U.S. for interim storage and then disposition of the spent fuel in the geologic repository are analyzed, assuming initial operation of the geologic repository begins in the year 1995 (a ten-year delay), in addition to the assumption of initial operation in the year 1985.

C Delays in opening the first U.S. geologic repository beyond the time frame originally analyzed in the draft EIS is a possibility. Therefore, Appendix A was added to provide the environmental analysis of foreign spent fuel storage for two additional cases assuming operation of the initial U.S. geologic repository is begun in the year 2010.

C The descriptive titles of the nine cases analyzed in the body of the EIS are given below.

Case A. Fuel Remains in Foreign countries -
No U.S. Support
(Option 3 Fuel Schedule)

Case B. Fuel Remains in Foreign Countries -
U.S. Supports Multinational Interim Storage
(Option 3 Fuel Schedule)

Case C. Fuel Remains in Foreign Countries -
U.S. Supports National Interim Storage
(Option 3 Fuel Schedule)

Case D. Fuel Shipped to U.S. -
Later Disposed of in U.S. Geologic Repository*
(Option 3 Fuel Schedule)

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* Analyzed, assuming initial operation of U.S. geologic repository
C begins in the year 1985 and in the year 1995.

Case E. Fuel Shipped to U.S. -
Later Returned for Reprocessing
(Option 3 Fuel Schedule)

Case F-1. Fuel Shipped to U.S. -
Later Reprocessed and Recycled in U.S.
(Option 3 Fuel Schedule)

Case F-2. Fuel Shipped to U.S. -
Later Reprocessed in U.S. - Pu and U Returned as
Refabricated Proliferation-Resistant Fuel
(Option 3 Fuel Schedule)

Case G. Fuel Shipped to U.S. -
Later Disposed of in U.S. Geologic Repository*
(Option 2 Fuel Schedule)

Case H. Fuel Shipped to U.S. -
Later Disposed of in U.S. Geologic Repository*
(Option 1 Fuel Schedule)

C The descriptive titles of two additional cases analyzed in Appendix A of this EIS are given below:

Case I. Fuel Shipped to U.S. -
Later Disposed of in U.S. Geologic Repository**
(Option 2 Fuel Schedule)

Case J. Fuel Remains in Foreign Countries -
No U.S. Support**
(Option 2 Fuel Schedule)

The operations involved in each case are shown in Table I-1. The facilities associated with these operations are described briefly in the following paragraphs.

- <u>The generic ISFS facility</u> is assumed to consist of a set of modular water-filled basins. The maximum capacity of a single C ISFS basin facility is assumed to be 18,000 MTU of spent fuel.

C * Analyzed, assuming initial operation of U.S. geologic repository begins in the year 1985 and in the year 1995.

** Analyzed, assuming initial operation of U.S. geologic repository begins in the year 2010.

• The generic geologic repository is assumed to be constructed in a salt formation. The selection of a salt formation as a reference for this analysis is not intended to indicate a preference for salt as a host material for geologic repositories. It is also conceivable that a technology other than conventional disposal may be chosen. Delay in startup of the U.S. repository beyond the year 2000 is treated in this EIS in Appendices E and A of Volumes 2 and 3 respectively. The type of repository is not expected to affect significantly the environmental effects considered in this volume.

• The generic fuel reprocessing plant (FRP) in the U.S. is assumed to have a processing rate of approximately 2500 MTU/yr for U.S. plus foreign fuels, if a U.S. decision is made in the future to proceed with reprocessing. Because the amount of foreign fuel (considered in this volume) to be processed in reprocessing plants abroad is much less than that in U.S. plants designed to process domestic and foreign fuel, the generic foreign reprocessing plant

TABLE I-1

Summary of Operations Involved in Cases

Case	*A*[a]		*B*[a]		*C*[a]		*D*	*E*	*F-1*	*F-2*	*G*	*H*	*I*	*J*
Foreign Spent Fuel Fuel Schedule Option[b]	3		3		3		3	3	3	3	2	1	2	2
Retained in Foreign Countries	●	●	●	●	●	●								●
Interim Storage in Foreign Countries Without U.S. Support	●	●												●
U.S. Supports Interim Storage in Countries of Origin Except Those Located in Sensitive Regions					●	●								
U.S. Supports Interim Storage in Multinational Storage Facilities Located in Countries Outside Sensitive Regions			●	●										
Spent Fuel Disposed of as Waste in Foreign Geologic Repositories		●		●		●								
Reprocessed in Foreign Countries[c]	●		●		●									●
Separated Plutonium and Uranium Recycled in Foreign Countries	●		●		●									●
Shipped to U.S. for Storage							●	●	●	●	●	●	●	
Returned to Foreign Countries								●						
Reprocessed in U.S.[d]									●	●				
Returned to Foreign Countries and Reprocessed[c]								●						
Separated Plutonium and Uranium Recycled in U.S.									●					
Separated Plutonium and Uranium Recycled in Foreign Countries								●		●				
Disposed of as Waste in U.S. Geologic Repository — Repository Startup Date 1985							●				●	●		
Disposed of as Waste in U.S. Geologic Repository — Repository Startup Date 1995							●				●	●		
Disposed of as Waste in U.S. Geologic Repository — Repository Startup Date 2010													●	

a. In Cases A, B, and C, disposition of the spent fuel by reprocessing and by disposal in a geologic repository is considered. In the first column, the fuel is assumed to be reprocessed. In the second column, the spent fuel is assumed to be disposed of as waste in a geologic repository.

b. As detailed in Section II-D, three different levels of foreign spent fuel (Options 1, 2, and 3) are identified in this study of the U.S. offer to store foreign spent fuel.

The Option 1 foreign spent fuel schedule includes fuel from countries inside sensitive regions. Acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

The Option 2 foreign spent fuel schedule includes the Option 1 fuel level and in addition, acceptance of spent fuel from a limited number of other countries with spent fuel storage problems (from a nonproliferation standpoint). Acceptance of fuel by the U.S. will be considered on a case-by-case basis.

The Option 3 foreign spent fuel schedule includes the Option 2 fuel level and in addition, acceptance of some of the spent fuel from a larger number of non-nuclear-weapons states. Again, acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

c. Reprocessing waste is disposed of in foreign geologic repositories.

d. Reprocessing waste is disposed of in U.S. geologic repository.

12-i is assumed to be smaller than the generic U.S. plant. The environmental effects per unit of fuel throughput from each of these facilities were assumed to be the same regardless of the assumed plant size. Collocated with each reprocessing plant is a mixed oxide (MOX) fuel fabrication plant (sized to handle the output of the FRP).

For purposes of this volume, fuel reprocessing plants coming online in the late 1990s are assumed to include equipment currently under development. This equipment will reduce and control releases of tritium, krypton-85, carbon-14, radioiodine, and particulates. In this volume, all U.S. and certain foreign FRP-MOX plants are
C also assumed to meet current and future requirements for proliferation resistance and safeguards; these features are assumed not to increase the environmental effects over previously analyzed FRP-MOX plants.

In all cases considered in this volume, facilities are assumed to be decommissioned after completion of the operating phase. The reference decommissioning mode is decontamination and dismantlement of the surface facilities, combined with some restriction of future subsurface activities at the geologic repository.

Since many areas are probably suitable for the construction
C of ISFS basins, geologic repositories, and FRP-MOX plants, a generic site environment was selected in this volume for quantitative assessment of the environmental effects from construction, operation, and decommissioning of these facilities and from transportation of spent fuel and wastes. The generic site is assumed to have the same characteristics for facilities located
1-b in the U.S. and in foreign countries. As discussed in the Foreword, DOE will prepare another EIS to provide environmental input into the selection of facilities if a decision is made to implement the Spent Fuel Storage Policy. Public input will be requested during (1) the scoping process for this EIS, (2) review of the draft EIS, and (3) the NRC licensing process.

Transportation of spent fuel and reprocessing waste involves the use of massive, heavily shielded shipping casks that are transported by truck, rail, and ship. About ten times more fuel
C can be shipped in a rail cask than in a truck cask. Additional casks must be made available for the spent fuel and waste shipments as the number of shipments increase. Spent fuel shipments to the U.S. from foreign countries are assumed to originate at a port near the foreign reactors and to travel by ship to a port near the U.S. storage basin. Eighty percent of the foreign LWR* fuel is assumed to be transported from the foreign docks to U.S. facilities in rail casks and the remainder in truck casks. All CANDU** fuel is assumed to be shipped in rail casks.

* LWR — Light Water Reactor.
** CANDU — CANadian Deuterium Uranium.

12-e The purpose of providing spent fuel storage in the U.S. for foreign fuels is to reduce the potential for proliferation of sensitive nuclear facilities and materials. Although quantification of nonproliferation is difficult and of questionable benefit, any reduction in proliferation potential is a major environmental and societal benefit. The benefits listed are in the form of policies adopted by individual nations, groups of nations, and by consensus within the international community. Examples of such benefits from the U.S. perspective include:

- Applying adequate and effective international safeguards to all civilian nuclear facilities
- Preventing the spread of nuclear explosive capability to additional foreign nations
- Limiting the number of sensitive nuclear facilities to that required to service the international nuclear fuel cycle and restraining the deployment of such facilities not currently required to serve the development and deployment of nuclear power generation
- Limiting the potential of diversion of weapons-usable nuclear materials from the nuclear fuel cycle
- Promoting establishment of new or stronger international institutions which will contribute to international assurance that nonproliferation undertakings are being observed
- Encouraging nations to adopt fuel cycle strategies that take proliferation resistance into account

For purposes of comparing the proliferation effects of the various cases analyzed in this volume, the following assumptions are made:

- Disposing of fuel in a geologic repository reduces the risk of diversion and reduces the nuclear proliferation potential.
- Reprocessing of spent fuel in the U.S. or abroad under international safeguards by using proliferation-resistant technologies would, in comparison with additional national reprocessing, be a gain for U.S. policy. However, spent fuel storage is more secure.

In the context of the U.S. nonproliferation goals, Cases A and J are least acceptable. In Cases A and J, the U.S. takes no action in regard to storage of spent fuel from foreign power reactors. Some nations lacking sufficient storage capability may turn to national reprocessing as an alternative. Other nations will contract with still other countries for reprocessing services. Thus, additional countries would acquire facilities capable of producing material usable in nuclear explosive devices, and sensitive materials might be stored in many countries, some in sensitive regions. The U.S., if this case were adopted, would be limited in its opportunity to promote its nonproliferation goals of forestalling the building of new reprocessing plants and of decreasing the widespread national storage of spent fuel containing plutonium.

Spent fuel remains in foreign countries in Cases B and C. In these cases, the U.S. would support either multinational storage (Case B) or national storage (Case C). The nonproliferation benefits of multinational storage are greater than national storage because the countries eligible for bilateral support of multinational storage would have to be outside sensitive regions and show financial capability to support an expanded spent fuel storage program once U.S. assistance stops. Multinational storage provides for removal of fuel from sensitive countries while national storage does not. Multinational ownership and/or operation of spent fuel storage facilities could also provide an additional barrier to diversion of material for reprocessing to obtain materials that could be used in nuclear weapons. In Case C, the national storage facility, which is located outside sensitive regions, would provide no fuel storage for countries in sensitive regions and in itself, would not achieve the nonproliferation goals of the U.S. This option could be used along with other options (e.g., Case H for fuel from sensitive countries) to implement the U.S. nonproliferation goals.

Cases D, E, F-1 and F-2 provide for spent fuel storage in the U.S. and the Option 3 fuel schedule. The Option 3 fuel schedule is assumed to be the highest level of participation by foreign countries. Four potential options for eventual disposal of foreign spent fuel are analyzed for the Option 3 fuel schedule to show the range of long term impacts of acceptance of foreign spent fuel in the U.S. for storage. Options for disposal include:

1) Disposition of foreign fuel in a U.S. geologic repository (Case D).

2) Return of foreign fuel for foreign reprocessing under conditions that meet nonproliferation objectives (Case E).

3) Reprocessing of foreign fuel and recycling of uranium and plutonium in the U.S. with a proliferation-resistant technology (Case F-1).

4) Reprocessing of foreign fuel in the U.S. and return of fabricated mixed oxide fuel to foreign countries not in sensitive regions (Case F-2).

Cases E, F-1, and F-2, in which the foreign spent fuel is assumed to be reprocessed either in the U.S. or abroad, are inconsistent with present U.S. policy. They are included for the sake of completeness as part of the NEPA process. If the U.S. agrees to the reprocessing of the fuel, it would be carried out under international safeguards with proliferation-resistant technologies that meet the nonproliferation objectives of the U.S.

C Cases G, H, and I are similar to Case D in that foreign fuel is stored in the U.S. and later disposed of in a U.S. geologic repository. The differences in these cases are the countries
C included in the policy, the amount of foreign fuel received by the U.S., and the startup timing of the geologic repository. Case H (Option 1 — the least amount of foreign fuel) involves only countries in sensitive regions. Cases G and I (Option 2) involve countries in sensitive regions plus a limited number of smaller countries in less sensitive regions with clearly identified spent fuel storage problems. Case D (Option 3 — largest amount of foreign fuel) includes countries in Case G, plus a very few, larger, industrialized, non-nuclear-weapons states.

In Case H, the spent fuel will be removed from countries in sensitive regions, a major objective of the U.S. nonproliferation policy. However, other foreign nations would have to choose a
C course of action for storage of their spent fuel. Spent fuel would be stored in a number of locations, and some countries might select reprocessing as an alternative even though adequate safeguards to meet nonproliferation objectives are not available. Larger, industrialized nations are better able to finance spent fuel storage facilities. They are more likely, however, to construct a reprocessing plant, either jointly or on an individual basis. Therefore, Case D, which includes larger, industrialized non-nuclear-weapons nations offers the highest benefits to the nonproliferation policy, because it provides the ability to influence the greatest number of countries to store spent fuel instead of reprocessing it.

Other than the effects on the nonproliferation objectives, the environmental effects believed to be of the greatest signifi-
C cance are given in Tables I-2 and I-3 for Cases A through H and in Table I-4 for Cases I and J. Tables I-2 and I-4 include only the environmental effects associated with interim storage of
C foreign spent fuel, and they are presented to allow a direct comparison with the environmental effects shown in Volume 2, <u>Storage of U.S. Spent Power Reactor Fuel</u> (which assessed only the interim storage of domestic fuel). Table I-3 includes both the effects from interim storage and disposition of foreign spent fuel for
C Cases A through H. Disposition effects were not determined for Cases I and J. Only interim effects were determined in Appendix A.

TABLE I-2

Summary of Environmental Effects From Interim[a] Storage of Foreign Spent Fuel

	A,B,C[b]	*D*	*D*	*E*	*F-1*	*F-2*	*G*[c]	*G*[c]	*H*[c]	*H*[c]
Year U.S. Geologic Repository Begins Initial Operation	1985	1985	1995	1985	1985	1985	1985	1995	1985	1995
Population Whole Body Dose Commitment, man-rem										
U.S. and Global Commons	0[d]	730	2840	980	1000	1000	170	1040	47	550
World	2.5	730	2840	980	1000	1000	174	1040	47	550
Occupational Exposure, man-rem										
U.S. and Global Commons	0[d]	440	1220	345	510	510	138	450	73	190
World	16	510	1270	370	570	580	157	470	82	200
Health Effects[e]										
C *U.S. and Global Commons*	0[d]	0.74	2.5	0.83	0.96	0.96	0.19	0.93	0.08	0.46
World	0.01	0.78	2.6	0.85	1.0	1.0	0.21	0.94	0.08	0.47
Accidental Deaths										
7-j *U.S. and Global Commons*	0[d]	1.6	2.4	0.87	1.8	1.8	0.47	0.82	0.22	0.38
World	0.4	1.6	2.4	1.2	1.8	1.8	0.47	0.82	0.22	0.38

C *a.* Does not include incremental environmental effects of mining and milling.

b. Case A effects are shown. The effects for Cases B and C are essentially the same.

c. Case G includes environmental impacts for receipt of Option 2 spent fuel in the U.S., and Case H includes environmental impacts for receipt of Option 1 spent fuel in the U.S.

d. In Case A no operations occur in the U.S. or the global commons. For Cases B and C, there are no operations with foreign spent fuel in the U.S. but some fuel may be shipped by sea between countries other than the U.S.

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. 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 Volume 2 for more detail on methodology used in determining health effects.)

TABLE I-3

Summary of Major Environmental Effects from Interim Storage and Disposition of Foreign Spent Fuel

	A,B,C[a]	*D*	*D*	*E*[a]	*F-1*[a]	*F-2*[a]	*G*[b]	*G*[b]	*H*[b]	*H*[b]
Year U.S. Geologic Repository Begins Initial Operation	1985	1985	1995	1985	1985	1985	1985	1995	1985	1995
Population Whole Body Dose Commitment, man-rem										
U.S. & Global Commons	5500	850	2950	6930	11,500	11,500	198	1080	67	570
World	7200	850	2950	8260	11,500	11,500	202	1080	67	570
Occupational Exposure, Man-rem										
U.S. & Global Commons	0	700	1480	440	5810	6060	228	540	118	235
World	8700	770	1530	7910	5870	6210	247	560	127	245
Health Effects[c]										
U.S. & Global Commons	3.2	1.02	2.8	4.3	11.1	11.3	0.28	1.02	0.12	0.51
World	10.5	1.06	2.8	10.6	11.1	11.4	0.30	1.03	0.13	0.52
Accidental Deaths										
7-j *U.S. & Global Commons*	0	3.4	4.2	1.6	9.4	10.6	1.1	1.5	0.56	0.72
World	7.9	3.4	4.2	8.3	9.4	10.9	1.1	1.5	0.56	0.72

a. Does not include incremental environmental effects of mining and milling. In Cases A,D,C,E, F-1 and F-2, it is assumed the foreign spent fuel is reprocessed and the recovered plutonium and uranium is recycled; reduced mining and milling requirements would result in a decrease of ~120 health effects (because of reduced lung exposure to the population and work force) and a decrease of ~31 in occupational deaths.

C *b.* Case G includes environmental impacts for receipt of Option 2 spent fuel in the U.S. and Case H includes environmental impacts for receipt of Option 1 spent fuel in the U.S.

c. 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 Volume 2 for more detail on methodology used in determining health effects.)

C | TABLE I-4

Summary of Environmental Effects from Interim Storage of Foreign Spent Fuel, 2010 Startup of U.S. Geologic Repository

Case	*I*[a]	*J*[b]
Year U.S. Geologic Repository Begins Initial operation	2010	2010
Population Whole Body Dose Commitment, man-rem		
U.S. and Global Commons	1400	0
World	1400	8.5
Occupational Exposure, man-rem		
U.S. and Global Commons	330	0
World	360	43
Health Effects[c]		
U.S. and Global Commons	1.0	0
World	1.1	0.04
Accidental Deaths		
U.S. and Global Commons	0.5	0
World	0.5	0.1

a. Case I includes environmental impacts for Option 2 spent fuel received in the U.S.

b. In Case J, no operations occur in the U.S. or the global commons.

c. 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 under this column along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

The scope of this volume is the environmental impact on the U.S. and global commons from implementation of the proposed foreign portion of the U.S. Spent Fuel Storage Policy and alternatives thereto. Tables I-2, I-3, and I-4 set forth the impacts on the U.S. and global commons. These cumulative impacts on the U.S. and global commons were calculated by determining the total world environmental effects less those associated with regional effects* resulting from operations in foreign nations. The world environmental effects are also set forth in Tables I-2, I-3, and I-4 for purposes of completeness. The environmental effects on the territories of foreign states are not assessed in this volume.

In this analysis, the effects from reprocessing of the foreign spent fuel are assessed for Cases A, B, C, E, F-1, and F-2. Although this analysis is concerned with operations associated with the back-end of the fuel cycle, if the fuel is reprocessed and the recovered plutonium and uranium recycled, a decrease in virgin uranium feed requirements would result. This in turn would lead to a reduction in mining and milling activities to provide uranium. The reduction in mining and milling activities would result in a significant decrease in radiation health effects to the population (primarily from a decrease in lung dose from radon gas) and in accidental mining and milling deaths to occupational employees. These reduced mining and milling effects exceed the increase in health effects and accidental deaths arising from the activities associated with the foreign spent fuel analyzed in this volume. However, the mining and milling activities are not included in the discussion of the effects for the different cases and are not shown in Table I-3 because these operations are not directly associated with the operations at the back-end of the fuel cycle that are directly affected by the Spent Fuel Storage Policy offer.

The population whole body dose commitments resulting from interim storage of the foreign spent fuel, given in Tables I-2 and I-4 range up to about 3000 man-rem. The population dose commitments range from about 70 to about 11,500 man-rem when interim storage and disposition of the foreign spent fuel are considered, as shown in Table I-3. Effects of long-lived nuclides in the 100-year period following the end of the study are also included in this table to provide an assessment of effects of persistent nuclides. The population doses shown in Tables I-2 and I-3 are a very small fraction of the whole body exposure to the world population of about 200,000,000,000 man-rem from

* The regional effects are those impacting on a hypothetical land area of 9 million km^2 (3.5 million mi^2) (an area equal to that of the United States) with the foreign nation carrying out the activities located at the center of that area.

C natural radiation sources in the same period. The world population
dose commitment in Table I-4 should be compared to 370,000,000,000
man-rem. This comparison value is higher than those for Tables
I-2 and I-3 due to different lengths of the study period. The
differences between the different cases are not judged to be of
sufficient importance to strongly influence the selection of the
case or combination of cases that best implements the U.S. offer
to store foreign fuel.

Occupational radiation exposures are also summarized in
C Tables I-2 and I-3 for Cases A through H and in Table I-4 for
Cases I and J. These exposures increase in the cases when initial
operation of the geologic repository is assumed to be delayed
C (Cases D, G, H, and I). The increases occur because of the larger
work force and longer period of operation at the ISFS basins. The
occupational dose is greatest for the cases with reprocessing, but
again, the doses are so low that they would not strongly influence
the decision of how to implement the U.S. offer to store foreign
fuel.

The radiological health effects calculated from the population
and occupational doses range from 0.01 to 2.6 when only interim
C storage of the foreign spent fuel is considered (see Tables I-2
and I-4) and from 0.13 to 11.5 when disposition of the foreign
7-a fuel is also considered (See Table I-3). For perspective,
C 120,000,000 health effects are expected to occur within the
world population from natural radiation during the same period
considered in Tables I-2 and I-3. If the period is extended to
include that used in Table I-4, the expected health effects will
be 220,000,000 from natural radiation. The number of acciden-
7-j tal deaths for the cases considered in this volume of the EIS
range up to 2.4 for activities associated with interim storage
of the foreign spent fuel. When activities associated with
disposition of the foreign spent fuel are included, the range
is up to 11. Again, these effects are small enough not to have
a significant effect on the selection of the policy which will
best implement the U.S. offer to store foreign fuel.

Analyses are also made of the environmental risks from major
abnormal events and accidents in the facilities considered in
this volume. These risks are shown to be very small and essentially
the same for Cases A through H. The environmental risks from
C abnormal events and accidents were not determined for Cases I and
J, but the risks for these cases would be proportional to those
of Cases G and A respectively corrected for program size and
program duration. The maximum individual dose commitments
following abnormal natural events (e.g., tornadoes) and severe
accidents (e.g., criticality) that may 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 extreme transportation accidents in which a
C shipping cask is breached. The consequences of transporting
low-level TRU waste from reprocessing was determined to be 4 rems
for an extreme accident. The consequence of an extreme accident
associated with spent fuel expected to be transported under this
policy is estimated to be somewhat lower, 1.6 rems. The extreme
accident which would result in a 1.6-rem body dose was developed
for a maritime accident. The accident is assumed to result in
simultaneous breaching of four large shipping casks. A comparable
extreme accident which would involve land transport would possibly
breach no more than a single cask and as such would result in
8-b a body dose of 0.4 rem. However, the risk of these events is
small because of the low probability of cask failure. No near-
term biological effects of any significance are expected from the
accidents analyzed.

Transportation and storage activities with spent fuel involve radioactive and fissionable material that can, under specific circumstances, be misused to create an unacceptable public consequence. However, spent fuel is relatively easy to protect because of its intense radiation and the technical problems associated with separating the plutonium it contains. In addition, the consequences from the most credible sabotage scenarios involving spent fuel are very small. Property damage resulting from sabotage incidents would consist mostly of localized contamination that would necessitate limited access until cleanup operations could be completed. Therefore, the spent fuel storage and transportation operations described in this volume do not impose an unacceptable safeguards risk or hazard to the public.

As discussed earlier, if in the future, the U.S. decides that the foreign spent fuel stored in the U.S. can be reprocessed and the separated plutonium and uranium fabricated into fuel assemblies, the reprocessing and refabrication would be carried out under international safeguards with proliferation-resistant technologies that meet the nonproliferation objectives of the U.S. This would include acceptable measures to reduce to acceptable levels the risk of theft or diversion of separated plutonium and sabotage of FRP-MOX facilities.

Resource consumption is small in all cases, although cases that include the assumption that the geologic repository is delayed require more energy and materials because of increased construction and the longer operation of ISFS basin facilities. Resource consumption is also greater if the decision is made to reprocess the foreign spent fuel either in the U.S. or abroad, but it is still small.

Releases of thermal and nonradioactive effluents, and secondary effects on biota are judged to be minor and are not discussed in this volume.

1-a Because of the preceding analyses of the various alternatives contained in this final EIS and the comments received on the Draft EIS (DOE/EIS-0040-D — Storage of Foreign Spent Power Reactor Fuel), DOE prefers the following case. The Spent Fuel Storage Policy should be implemented, and the U.S. Government should offer to take title to foreign spent fuel from Option 2 countries on a case-by-case basis. This fuel would be stored in ISFS facilities located in the U.S. as identified in Case G. It is assumed for purposes of analysis that this fuel will eventually be disposed of as waste in a U.S. geologic repository. It should be emphasized that DOE is not making a choice between reprocessing and geologic storage at this time. Further, DOE proposes to continue to support multinational storage, not by subsidies, but by discussion with foreign nations.

REFERENCES FOR SECTION I

C 1. 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).

6-b 2. 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

The environmental aspects of alternative ways of implementing the offer made by the U.S. in October 1977, to accept limited quantities of foreign spent power reactor fuel for storage, when such action would further nonproliferation objectives, are analyzed in this volume. The impacts associated with not implementing the policy are also analyzed. This volume covers the environmental effects on the U.S. and the global commons* and on the world. However, in order to avoid any infringement on sovereignty of other nations, the assessments in this volume exclude local impacts of the U.S. Spent Fuel Storage Policy on the territory of individual foreign nations.

The offer to accept foreign spent fuel for storage in this country is part of a much larger proposed program involving storage by the U.S. Government of spent fuel from domestic power reactors. This domestic program is addressed in Volume 2, Storage of U.S. Spent Power Reactor Fuel. Since the amount of foreign fuel expected to be accepted for storage in the U.S. is much less than the amount of U.S. fuel expected to be stored under the program, the environmental impacts of the foreign offer are given in this volume as increments to the domestic aspect of the program. Predicting the exact quantities of foreign spent fuel that may be sent to the U.S. under the October 1977 offer is not possible because this will depend upon a number of variables, including the policy and economic decisions of foreign governments and utilities on the optimal means of handling their spent fuel. Therefore, a range of effects spanning the minimum and maximum quantities of spent fuel that may reasonably be expected to be sent to the U.S. will be described in this volume.

Estimates of the nonproliferation implications of the U.S. offer are also necessarily judgmental and, to some degree, speculative for similar reasons. For example, it is not possible at this time to forecast how nations that do not accept or do not qualify for the U.S. offer will choose to dispose of their spent fuel. Such decisions will be based upon the cost and availability

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* The environmental effects to the combined U.S. and global commons are the total world environmental effects less those associated with foreign regional[1] effects from foreign national operations. The regional effects are those associated with a land area of 9 million km^2 (3.5 million mi^2) (an area equivalent to the U.S.) with the foreign nations at the center of that area.

of alternatives, including the U.S. storage offer, national fuel cycle plans, availability of multinational facilities, expanded national storage, and nonproliferation considerations. Possible alternatives may include expanded national interim or long-term retrievable storage, terminal geologic disposal, or reprocessing to separate fission products from plutonium and uranium. Furthermore, some of the benefits expected from implementation of the policy are nonquantifiable, depending upon diplomatic outcomes, examples set, and follow-up actions by other nations.

B. United States Spent Fuel Storage Policy

On April 7, 1977, the President announced that because of the proliferation risks involved, the U.S. would defer the commercial reprocessing of spent fuel and the recycling of recovered plutonium and uranium into light water reactors (LWRs). Commercialization of the breeder reactor in the U.S., which had been expected to become a major producer and user of plutonium, would also be delayed. In the interim, the U.S. would study alternative fuel cycles that would avoid or minimize access to separated plutonium, a material directly usable in nuclear weapons. The President also asked other countries to proceed cautiously with these technologies and to join with the U.S. in a broad-based international evaluation of alternative fuel cycles and processes that might reduce the risks of nuclear proliferation.

This change in policy created uncertainties for the domestic nuclear power industry. For many years, reprocessing and recycling had been considered part of the solution to disposal of spent fuel. A new policy taking into account the deferral of these activities was needed.

Accordingly, in October 1977, the President announced that the U.S. Government was proposing to accept and take title to spent fuel from utilities upon payment of a one-time storage fee designed to recover all costs. Delivery of the spent fuel to an approved storage site would be at user expense. No immediate credit would be given for the value of the uranium or plutonium remaining in the spent fuel. If the U.S. decided in the future to opt for commercial reprocessing, then the spent fuel and part of the storage fee would be returned, or the customer would receive compensation for any net fuel value.

As part of this policy, the U.S. announced that it was prepared to accept limited quantities of foreign spent fuel under the same conditions applying to domestic utilities when this action would "contribute to meeting nonproliferation goals."

At the same time, the U.S. would encourage other nations to develop their own storage plans to support studies of regional or international storage sites. Basically, the U.S. has assumed that other nations would assume the primary responsibility for solving their own spent fuel problems.

U.S. storage of limited quantities of foreign spent fuel is designed to demonstrate the feasibility of alternatives to the premature reprocessing of spent fuel and the recycling of plutonium. It is intended as a contribution to international and national resolution of the spent fuel problem. The acceptance of foreign spent fuel by the U.S. is intended to encourage other national and international efforts of a similar sort. This combination of efforts would help other nations in exercising caution in moving toward a plutonium economy and would help to provide time to evaluate and develop more proliferation-resistant technologies for the next generation of reactors and fuel cycles. Nations with limited local storage capacity would have an alternative to reprocessing as a step in waste management. In some cases, countries would have no immediate choice but to move toward reprocessing unless the U.S. can provide them with a practical alternate option. Overall, the U.S. Spent Fuel Storage Policy would introduce a valuable element of flexibility into international planning for the nuclear fuel cycle.

12-p Foreign fuel returned to the U.S. or transferred to multinational storage facilities under this policy will be on a voluntary basis. Negotiations between the U.S. and foreign nations will be on a case-by-case basis. DOE believes it would be unreasonable to assume in this policy that all returns could be on a mandatory basis for the following reasons:

- As a practical matter, the U.S. cannot remove large quantities of spent power reactor fuel from a foreign nation without the cooperation of the foreign nation or without using military force.

- The U.S. nonproliferation goals as a whole require voluntary broad-based international cooperation to succeed. A policy of mandatory returns would be interpreted by many nations as coercive and discriminatory and would, on balance, reduce the inclination of other nations to cooperate with the U.S.

- A policy of mandatory returns would require unilateral changes in present contracts and understanding governing U.S. supply of nuclear fuel. Such action would undermine the reputation of the U.S. as a reliable supplier, thereby reducing the U.S. influence in international nuclear matters.

Plutonium in spent fuel cooled for several decades is more accessible to would-be diverters. If other nations, which do not choose to accept the U.S. storage offer, emulate U.S. policy with respect to storing spent fuel within their respective territories, then they will be accumulating stocks of spent fuel which could be later reprocessed to recover the contained plutonium. However, despite these possibilities, spent fuel storage is still less of a proliferation risk than fuel cycles which use or build up stocks of separated plutonium or mixed oxide fuels containing plutonium. Furthermore, multinational spent fuel storage regimes, as described later, would result in improved international safeguards, would provide interim storage capability until permanent disposal in a geologic repository of spent fuel becomes available and would improve the proliferation resistance of storage arrangements.

1-b If a decision is made to implement the policy, an away from
1-c reactor-spent fuel storage facilities EIS (AFR EIS) will be prepared to provide the environmental input on the selection of facilities for policy implementation. The demand for spent fuel storage will be developed by using the latest available data as supplied by domestic and foreign 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 transportation effects associated with the available options will be evaluated.

1-b 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 NRC. The NRC licensing process will provide additional public input.

C. Range of Activities

The range of activities described in this analysis includes:

- Acceptance of foreign fuel
- Support of foreign storage facilities
- No action.

These are discussed briefly in C.1, C.2, and C.3 of this section.

C.1 Acceptance of Foreign Fuel

As part of the Spent Fuel Storage Policy, the U.S. announced that it would be prepared to accept limited quantities of foreign spent fuel under the same conditions which apply to domestic utilities described in Volume 2 when this action would contribute to meeting nonproliferation goals as noted in Section II B.

C.2 Support of Foreign Storage Facilities

As part of this policy, the U.S. would encourage other nations to develop their own storage plans, and the U.S. would support studies of regional or international storage sites. Basically, the U.S. assumes that other nations would retain the primary responsibility for solving their own spent fuel problems.

The U.S. could choose to support multinational storage arrangements outside the continental United States. Formal arrangements could take the form of a multinational storage facility under specific country ownership and/or operation, or under the auspices of an existing international organization, e.g., the International Atomic Energy Agency. The siting of such facilities would be by international agreement but, in all cases, they would be located outside sensitive regions. U.S. assistance to such arrangements would be contingent on the degree to which they contributed to this nation's nonproliferation objectives. Depending upon the circumstances, the U.S. might be a direct participant or might limit its role to providing
12-j technical and/or financial assistance. One possibility might be to locate an ISFS facility on an island. Currently, an island storage concept is being considered by the U.S. Government and at least one other country located in the Pacific Basin. This concept, although not analyzed specifically in this volume, is considered to be a possible suboption of either multinational or bilateral type facilities.

Another option would be to support the construction of storage facilities abroad on a bilateral basis. Eligible countries would be located outside sensitive regions and would be financially capable of supporting an expanded storage program once initial U.S. assistance terminated. In each instance, cooperation would offer nonproliferation benefits to U.S. policy. Decisions to offer U.S. assistance would be made on a case-by-case basis. This assistance could take the following forms: assistance in increasing the density of existing onsite reactor storage pools as described in Volume 2 of this EIS through reracking and the installation of
C neutron-absorbing racks, etc., or through assistance in the construction of ISFS storage facilities.

C.3 No Action

C The effects of the U.S. not providing any offer to foreign countries as described in either C.1 or C.2 of this section are also considered. In this case, each foreign country is assumed to proceed with its current plans for disposing of the spent fuel from its reactors by 1) reprocessing the spent fuel and recycling the recovered plutonium and uranium and then disposing of the reprocessing waste in a foreign geologic repository or 2) disposing of spent fuel as waste in a foreign geologic repository.

D. Criteria of Offer to Accept Foreign Spent Fuel

Predicting the exact quantity of foreign spent fuel that may be sent to the U.S. under the October 1977 offer is not possible because it will depend upon a number of variables, including the policy and economic decisions of foreign governments and utilities on the optimal means of handling their spent fuel.

C Certain technical factors will also affect the actual volume of spent fuel returned to the U.S. including:

- Actual rate of reactor burnup and the degree to which operators adhere to optimum discharge schedules.
- Unforeseen factors which affect the actual growth in nuclear power utilization abroad.

Therefore, a range of effects spanning the minimum and maximum quantities of spent fuel that might reasonably be expected to be sent to the United States will be described.

1-f The implicit assumption made in establishing the amount of foreign fuel that might be shipped to the U.S. was that it would be cooled on the average of about 5 years. For environmental effects, the fuel was assumed to be cooled on an average of 4 years. Specific fuel shipping schedules have not been established; these will be negotiated on a case-by-case basis, and if receipt of short-cooled spent fuel from sensitive countries benefits the U.S. nonproliferation objective, it could be shipped.

1-f This volume analyses the impact of receiving spent fuel from foreign countries to increase U.S. nonproliferation objectives. As indicated in this volume, the desired objective probably will not require acceptance of all of the spent fuel from a sensitive foreign country (Option 1 country). The policy does not restrict the U.S. to receiving only spent fuel cooled a minimum of five years. When it is desirable from a nonproliferation standpoint, fuel cooled less than 5 years could also be received.
12-k Leaving a 5-year accumulation of spent fuel in sensitive countries
1-f may slightly increase the proliferation potential compared with removal of all of the spent fuel from sensitive countries. DOE does not believe, however, that proliferation potential is proportional to the amount of spent fuel stored in sensitive foreign countries; however, it is more a function of disposal needs and alternatives available to meet these needs.

12-k The above conclusions were reached because

- First, the benefits of the U.S. storage offer are not directly proportional to the volume of material shipped to this country. The policy will have a nonproliferation benefit to the degree to which it assists individual nations in avoiding early reprocessing as a policy choice, to the degree to which it allows individual nations the time to arrive at more permanent multinational, or where prudent, national arrangements for spent fuel storage as an alternative to early reprocessing, and to the degree to which the foregoing points encourage nations with nuclear energy programs to consider long-term spent fuel storage as an economically viable approach. It is not possible to measure in a quantitative fashion these influences in national nuclear energy decisions.

- Second, while it is true that stored spent fuel is a potential source of plutonium for any nation in possession of such material, it is also true that spent fuel is relatively less of a proliferation risk than separated plutonium or contracts which will lead to the separation of plutonium. The radiation barrier of spent fuel provides an inherent degree of protection. International safeguards are applied to nearly all of the spent fuel storage facilities in the non-Communist world. These IAEA safeguards can be applied with a greater confidence to stored spent fuel than to reprocessing plants or to separated plutonium, and, when combined with the radiation barrier in the material itself, provide greater assurance to the international community of timely warning in the event of any attempt to divert the material for weapons purposes. To the degree to which the U.S. spent fuel storage program

12-k discourages early reprocessing, these nonproliferation advantages will be retained. Shipment of some fuel to the U.S. will involve the sending country in a commitment to avoid premature reprocessing in favor of long-term spent fuel storage.

- Third, the U.S. will encourage countries located in sensitive regions to reduce their inventories of spent fuel to the lowest possible levels, initially by shipments to the U.S. and over the longer term by participating in multinational storage arrangements. Even in instances in which all of the fuel is not returned, the U.S. will obtain a nonproliferation benefit to the degree that the country concerned becomes committed to storage as compared with premature reprocessing. Such a commitment would enhance international confidence in the observance of international safeguards and contribute to a reduction of tensions in regions in which countries build such confidence.

- Fourth, the U.S. offer to store foreign fuel is not an isolated element of nonproliferation policy. It is part of a larger strategy designed to discourage the appearance of potential weapons-usable materials in the fuel cycle and the spread of sensitive facilities which can produce such material. The policy will result in benefits to the degree that it contributes to this overall strategy. However, it should be noted that storage alone is not regarded as the total solution to outstanding nonproliferation issues and problems.

It should also be noted that benefits would be achieved if countries located in sensitive regions made commitments to multinational spent fuel storage or shipped their fuel to the United States. These options are identified in this volume, and also groups of countries which could be eligible for the U.S. offer are identified to illustrate how these benefits would apply. Since a generic analysis is made in this volume, further precision is not possible.

In the following sections, three conceptual levels of foreign fuel deliveries (Options 1, 2, and 3) that may be involved in the implementation of the President's offer to store foreign spent fuel under this policy are described. These options (Table II-1) represent progressively larger increments of fuel that may be received, each increment from an additional category of countries. This breakdown is provided so that the nonproliferation benefits
C of different types of offers may be analyzed. After the three options were defined, based upon word description of each option, a list of potentially eligible countries was compiled. Total

TABLE II-1

Foreign Spent Fuel Delivered to United States, MTU

	Countries in Sensitive Regions (Option 1)					
	LWR		*HWR*		*Total*	
FY	*Annual*	*Cumu-lative*	*Annual*	*Cumu-lavive*	*Annual*	*Cumu-lative*
1983	30	35	75	75	110	110
1984	20	55	30	105	50	160
1985	20	70	45	150	65	225
1986	35	110	35	186	70	295
1987	30	140	50	235	80	375
1988	50	190	40	275	90	465
1989	45	235	50	325	95	560
1990	55	290	55	380	110	670
1991	55	345	60	440	115	785
1992	60	405	60	500	120	905
1993	65	470	65	565	130	1035
1994	70	540	65	635	135	1170
1995	75	615	70	700	145	1315
1996	80	690	70	775	150	1465
1997	90	780	70	845	160	1625
1998	95	875	75	920	170	1795
1999	100	980	75	995	180	1970
2000	110	1085	80	1075	190	2160

	Nonproliferation Benefits - Low Option (Option 2)					
	LWR		*HWR*		*Total*	
FY	*Annual*	*Cumu-lative*	*Annual*	*Cumu-lative*	*Annual*	*Cumu-lative*
1983	50	50	165	165	220	220
1984	55	105	70	235	125	340
1985	25	130	70	305	95	435
1986	70	200	70	375	140	575
1987	40	240	75	450	115	690
1988	105	345	90	540	195	885
1989	100	445	110	650	210	1095
1990	110	555	115	765	220	1320
1991	115	670	120	880	230	1550
1992	120	790	120	1005	240	1795
1993	125	915	125	1130	250	2045
1994	135	1050	130	1260	265	2310
1995	150	1195	135	1395	285	2595
1996	165	1365	140	1535	305	2900
1997	185	1550	145	1680	330	3230
1998	200	1755	150	1830	350	3580
1999	220	1975	150	1980	375	3955
2000	245	2220	155	2135	400	4355

	Nonproliferation Benefit - High Option, (Option 3)					
	LWR		*HWR*		*Total*	
FY	*Annual*	*Cumu-lative*	*Annual*	*Cumu-lative*	*Annual*	*Cumu-lative*
1983	180	180	360	360	541	540
1984	85	270	330	690	417	960
1985	105	370	340	1030	443	1400
1986	120	490	500	1530	620	2020
1987	140	630	400	1930	540	2560
1988	180	810	260	2190	440	3000
1989	210	1020	270	2460	480	3480
1990	250	1270	280	2740	530	4010
1991	300	1570	300	3040	600	4610
1992	350	1920	310	3350	660	5270
1993	420	2340	330	3680	750	6020
1994	480	2820	350	4030	830	6850
1995	540	3360	360	4390	900	7750
1996	590	3950	380	4770	970	8720
1997	670	4620	410	5180	1080	9800
1998	740	5360	430	5610	1170	10,970
1999	800	6160	460	6070	1260	12,230
2000	870	7030	480	6550	1350	13,580

C spent fuel discharged for each group of countries was calculated as a function of projected growth in nuclear power utilization under normal reactor operation conditions.

12-h Country-specific data have not been included in this final EIS for several reasons. Many nations regard long-term fuel cycle policy and policy regarding the role of nuclear energy in national energy planning as sensitive matters protected by sovereign prerogatives. Classified assessments of the nuclear energy programs of potentially eligible countries were used to assess each option developed; therefore, details are not discussed to protect confidences exchanged between the United States and other governments. Since this volume of the final EIS is a generic analysis being made before programmatic commitments, aggregate data establishing the maximum action were used to provide a basis for analyzing the potentially adverse impacts on the environment. Aggregate figures also average out the degree of uncertainty with respect to spent fuel returns from any one country. Until the U.S. makes a firm offer accompanied by contractual terms and criteria for acceptance, it will not be possible to determine precisely which countries will choose to ship fuel to this country.

The amounts of spent fuel from Option 3 countries is assumed to be conservative and forms the upper bound of DOE policy at this time. Further, the amount of spent fuel in the other options (1 and 2) is lower. The split between LWR and CANDU type is arbitrary; some guidance was obtained from standard sources on existing and planned reactor configurations in foreign countries.[2,3,4]

C The amount of foreign fuel considered in this volume is the projected fuel discharged up to the year 1995. It is expected
12-f that this spent fuel would be received through the year 2000. DOE has no plans to accept foreign spent fuel indefinitely. It is DOE's objective to promote as rapid a transition as possible to national and multinational arrangements acceptable from the nonproliferation perspective for disposition of spent fuel.

D.1 Option 1, Countries in Sensitive Regions

Under Option 1, the U.S. would accept spent fuel on a case-by-case basis only from countries located in sensitive regions where the protracted storage of even this material might be judged inappropriate or troublesome in terms of nonproliferation concerns. As used in this analysis, the term "sensitive regions" means areas of the world in which international tensions are high, and there is a risk of violent conflict. The term also applies to areas in which a country's nuclear power program may represent an additional source of international tensions per se. In most cases, the U.S. acceptance of fuel would be limited to countries that have agreements for cooperation with the U.S. for peaceful use of nuclear energy. However, in some cases, the U.S. might accept spent fuel from other nations.

The offer would apply to fuel that had cooled sufficiently to allow safe transport and would not encourage the sending countries to build up substantial local spent fuel storage capability. Under this option, a few countries may wish to avail themselves of the U.S. spent fuel storage offer as a way of demonstrating their intentions to observe nonproliferation obligations, and in so doing, contribute to mutual confidence and a reduction of hostility and suspicion.

Precisely which countries or regions may at any given time be covered under this option, or what quantities of spent fuel may be involved during a given period is difficult to specify. However, the quantities of spent fuel likely to be included are modest. At a maximum, this material would represent about
C 3% of total projected U.S. spent fuel stored under the U.S. Spent Fuel Storage Program.

The nonproliferation impacts of Option 1 may be summarized as follows: Removing spent fuel from a region subject to international tension could increase confidence that nonproliferation obligations will be observed and could reduce fears about possible misuse of the nuclear power programs in the nations concerned. Reductions in spent fuel stocks would limit the material available for potential reprocessing operations and, therefore, reduce the risk that separated plutonium might be introduced into the region. These countries would be provided with a practical alternative to reprocessing or transfer of spent fuel to another country for reprocessing. From the U.S. perspective, such opportunities may remove diplomatic irritants in relations with the countries in question. Countries in a particular region could improve confidence in each other's observance of nonproliferation obligations by shipping spent fuel to the U.S. or other locations outside the area.

On the other hand, some major policy costs may be involved in implementing Option 1. The limited nature of the U.S. offer may be interpretated by ineligible nations as discriminatory. Because spent fuel storage is a service with a definite economic worth and a value in improving the public acceptance and operational efficiency of a nuclear power program, a limited offer to countries in adversity, facing regional political tensions or situations that raise nonproliferation concerns, may also be interpreted as a form of subsidy. Thus, those nations of greatest concern from a nonproliferation standpoint would be the beneficiaries, whereas nations more supportive to United States nonproliferation objectives or in more stable regions would not benefit.

D.2 Option 2, Nonproliferation Benefits — Low Option

Under Option 2, the U.S. would accept spent fuel on a case-by-case basis from the countries covered in Option 1 and in a limited number of other countries where there is a nonproliferation benefit and the countries have no ready alternative solutions for spent fuel disposition that are acceptable from a nonproliferation standpoint.

Illustrative nonproliferation benefits may include continued commitment of adherence to the Nuclear Non-Proliferation Treaty, (NPT)[5] or to the Tlatelolco Treaty,[6] or acceptance of full-scope international safeguards on nuclear facilities. Countries that play a key role in evolving useful international fuel cycle arrangements or that agree to renegotiate their agreements for cooperation with the United States to include the conditions established in the Nuclear Non-Proliferation Act of 1978 might also be given preference. The United States might also give preference to countries which do not undertake reprocessing or that suspend conventional reprocessing activities, or that avoid entering into major new commercial reprocessing contracts with third countries. Illustrative evidence that a country has no ready solution to spent fuel disposition could include a temporary shortage of local spent fuel capacity, an inability to dispose of spent fuel domestically, e.g., on geologic or demographic grounds, or unavailability of anticipated spent fuel storage in another country. In general, countries located outside sensitive regions as defined in Option 1 would be expected to make good faith efforts to establish or expand local spent fuel storage capacity.

A number of small industrialized countries have not planned interim, retrievable, or terminal geologic storage for their expected spent fuel on the assumption that reprocessing would take place. In several countries, reactor licensing and operating rules or policies assumed reprocessing, causing governments and utilities to plan only for a limited capability to store spent fuel at power stations. In the absence of more attractive alternatives, a few of these countries may opt for reprocessing.

If Option 2 were implemented, the small industrialized countries would have an alternative to reprocessing. However, forecasting the precise quantities of spent fuel that may be sent to the U.S. under this option is difficult. Because more countries are included, the quantities will be larger than those proposed under Option 1, but still relatively small when compared with the quantities involved in the U.S. domestic storage program. If the foregoing categories are taken into account, then spent fuel shipments to the U.S. under Option 1 might be twice that for
C Option 1 or about 6% of the total projected U.S. spent fuel stored under the U.S. Spent Fuel Storage Program.

In addition to the nonproliferation implications of Option 1, Option 2 would have the following effects. Additional countries may be induced to forego premature reprocessing. Nations without suitable local disposal sites may be able to obtain the time to explore regional or international cooperation for spent fuel storage. Spent fuel storage in the U.S. might provide an incentive for additional countries to accept more extensive nonproliferation assurances, to adhere to the NPT,[5] or to adhere to the Tlatelolco Treaty.[6] The U.S. would approach the search for acceptable international fuel cycle arrangements with the added advantage of having made a positive contribution. Other countries might then be motivated to make their own contributions.

On the other hand, acceptance of Option 2 fuel for storage could reduce the motivation for other countries to find their own solutions to the storage problem for spent fuel. The storage issue involves questions of public acceptance and cost which every nuclear power nation must eventually face for itself. However, the U.S. could limit this potential by imposing strict ceilings on the quantity of fuel to be accepted from a given country and perhaps also a fixed time period during which shipments could be made. Such provisions would reinforce the limited, transitional nature of the U.S. offer.

D.3 Option 3, Nonproliferation Benefits — High Option

The U.S. would accept spent fuel from countries in sensitive regions (Option 1 countries), from other presumably smaller countries with clearly identifiable storage problems (e.g., Option 2 countries), and from some of the larger, industrialzed, non-nuclear-weapons states. The total represents 10% of all five-year-old spent fuel from noncommunist countries.

Receipt of spent fuel in this option would be taken on a case-by-case basis when U.S. nonproliferation interests would be served and there would be an apparent need for the action. This option includes: 1) cases in which reprocessing is likely to be a probable alternative to storing fuel in the U.S.; 2) cases in which U.S. acceptance would be offered under terms that would encourage the sending country to develop alternatives to national reprocessing, including investigation of multinational or national storage facilities; and 3) a larger number of cases in which nonproliferation treaty adherence or similar actions might be encouraged. Option 3 differs from Option 2 by expanding the scope of the offer to include a very few non-nuclear-weapons countries with larger nuclear power programs. In no instance would the U.S. offer be made for all the spent fuel generated in large nuclear power programs but only for specific amounts of spent fuel for which the needs and nonproliferation benefits described above are relevant.

Many of the observations applicable to the spent fuel storage situations discussed under Option 2 apply here. While some of the countries in Option 3 may be considering acquiring their own reprocessing capabilities, the U.S. offer to accept their spent fuel may assist in deferring new investments. Under Option 3, the quantity of spent fuel shipped to the U.S. would
C represent about 19% of the total projected U.S. spent fuel stored under the U.S. Spent Fuel Storage Program.

12-m The nonproliferation effects of Option 3 are potentially the most comprehensive of the three options since it provides the ability to influence the greatest number of countries to store instead of premature reprocessing of spent fuels. Removal of spent fuel from sensitive regions would be encouraged as in the
12-m other options. The industrial countries are important as trend-setters for the international community and as potential contributors to establishing multinational storage facilities. The more comprehensive nature of the offer under Option 3 would make it appear less discriminatory and, therefore, more attractive to all potentially eligible and cooperating countries. Decisions by some of the larger industrialized countries to defer reprocessing might have beneficial precedential impacts on the international community's approach to the nuclear fuel cycle. These nations also have the financial and technical resources to support the study and the possible creation of national or multinational spent fuel storage facilities. Adherence to the NPT treaty could be encouraged. In general, this option would contribute to improved international cooperation and a sense of common purpose in the nuclear area and would increase the effectiveness of U.S. nonproliferation efforts.

D.4 Combined Domestic and Foreign Schedules

The three assumed foreign spent fuel options, described in the previous sections are presented on Figure II-1 in addition to the estimated amount of domestic fuel (Volume 2). The domestic fuel estimate is given to provide perspective to the foreign fuel options. As shown, the foreign increment is small for all three options.

E. Long-Term Implication of Policy Alternatives

Several alternatives for long-term disposition of the spent fuel are considered in this volume. These are briefly listed below and described more fully in a subsequent section.

- Spent fuel is disposed of as waste in a geologic repository.
- Spent fuel is reprocessed in the U.S., and the plutonium recycled in power reactors in the U.S. or returned to the foreign countries of the fuel origin.
- Spent fuel may be reprocessed outside the U.S. In this case the foreign spent fuel stored in the U.S. would be returned to the country of origin for reprocessing.

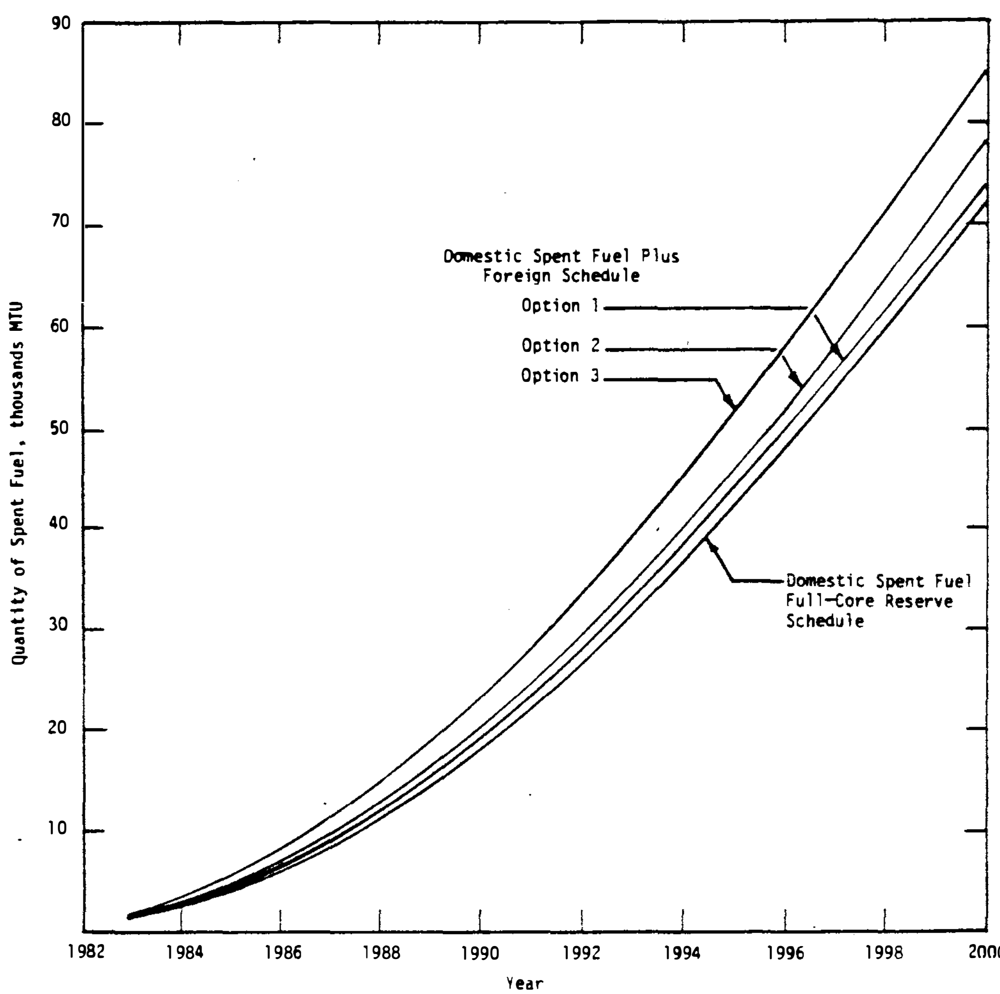

FIGURE II-1. Cumulative Foreign Plus Domestic Spent Fuel

F. Technical Description

F.1 Characteristics of Spent Fuel

The new policy does not exclude any type of power reactor fuel. However, two types of fuel are expected to predominate: light water reactor (LWR) and heavy water reactor (HWR) fuels.

The fuel currently used in LWRs is uranium dioxide in which the readily fissionable uranium-235 in the uranium has been enriched from natural abundance (0.7%) to 3 or 4% uranium-235. The LWR fuel rods, in the form of uranium dioxide pellets encased in either stainless steel or zirconium alloy (Zircaloy) tubes, are assembled into bundles (fuel assemblies) in a square array. Each rod is spaced and supported by grid structures and end pieces. Two types of LWR fuel are in use. Although similar in design, the fuel assemblies for pressurized water reactors (PWRs) and boiling water reactors (BWRs) differ somewhat in configuration as shown in Figure II-2. They also differ in size and in the quantity of fuel contained.

The predominant HWR fuel is CANDU (CANada Deuterium Uranium) fuel. CANDU fuel rods contain natural uranium (0.7% uranium-235) as uranium dioxide in a Zircaloy fuel sheath. The fuel rods are combined into a bundle with varying numbers of rods. Figure II-3 shows a typical 37-element fuel bundle. Each CANDU bundle is about 50 cm (20 in) long.

When fuel can no longer sustain a chain reaction at economic power levels, it is considered to be spent and removed from the reactor. About one-third to one-fourth of the LWR fuel is removed each year and replaced by fresh fuel. In a CANDU reactor with online fueling, the fuel remains in the reactor core for about one year. At discharge, the LWR fuel still contains fissile isotopes (about 4 g of fissile plutonium and about 8 g of uranium-235 per kg of uranium) and about 98% of the uranium-238 originally charged. CANDU fuel contains about three-quarters of the plutonium and uranium-235 per unit of total uranium that is contained in LWR fuel. In addition to the plutonium and uranium, all of the spent fuel contains large amounts of radionuclides formed during irradiation. These radionuclides occur both in the uranium oxide 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.

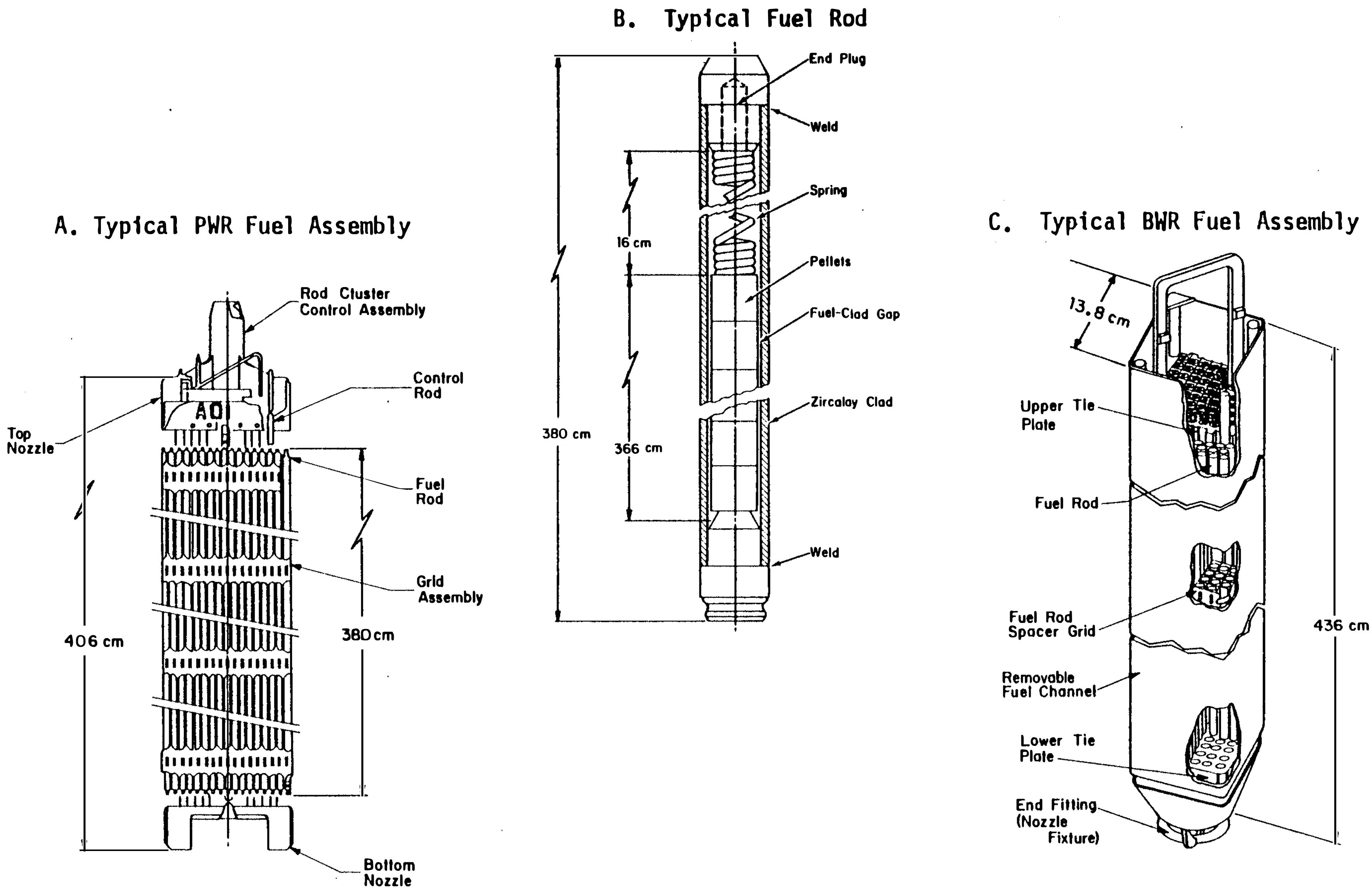

FIGURE II-2. Typical LWR Fuel Assemblies

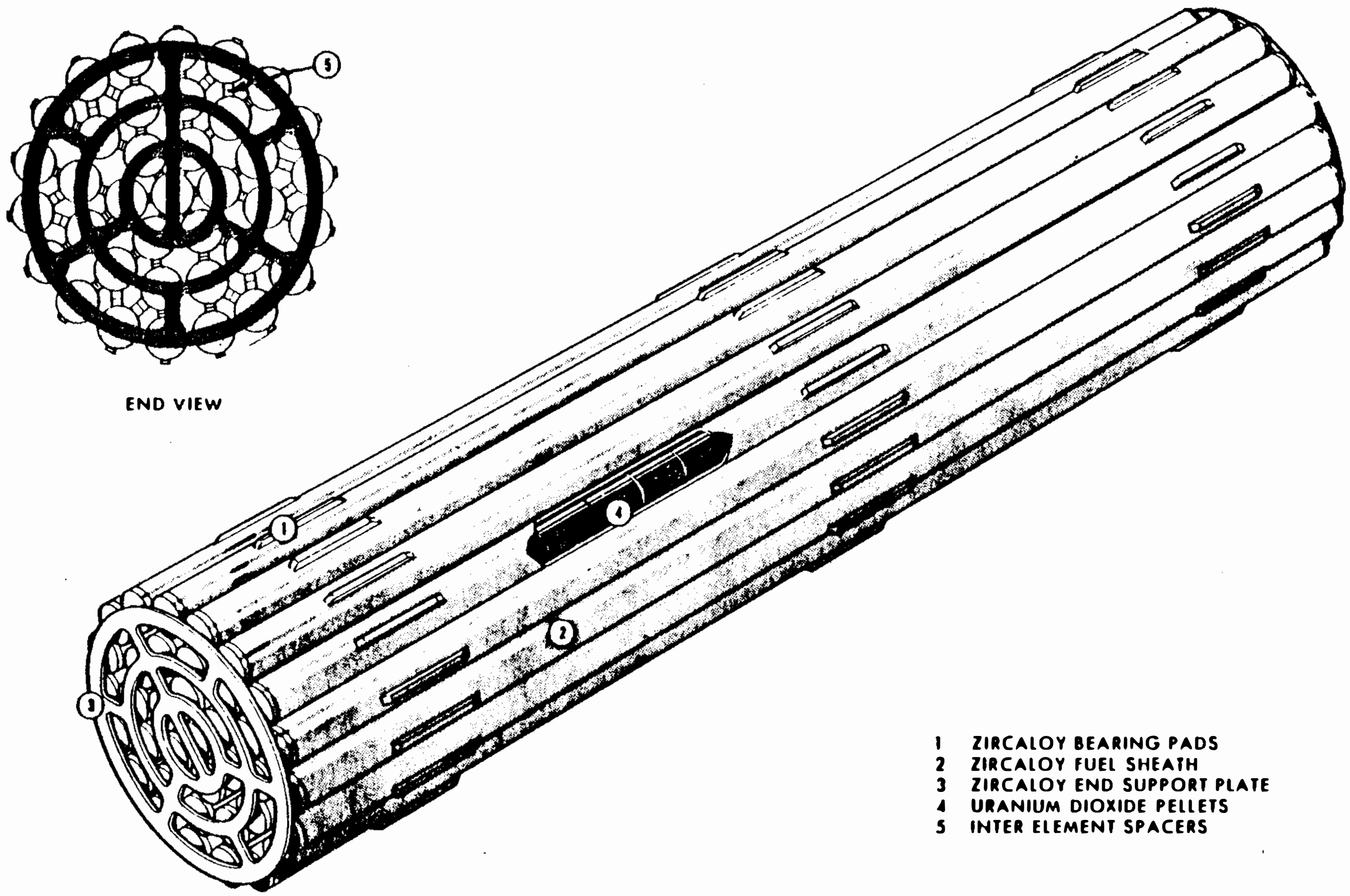

FIGURE II-3. Thirty-seven Element CANDU Fuel Bundle

Concentrations of the more-significant radionuclides and heat generation from typical PWR and CANDU fuel were calculated with the ORIGEN[7] computer code. They are shown in Table II-2 for fuel at time of discharge and at two and five years after discharge. Table II-2 includes only the radionuclides that contribute significantly to offsite dose when released in the quantities assumed in this environmental statement. Activities are shown for activation products (primarily in the hardware components), fission product (in the fuel matrix), and transuranic elements (also in the fuel matrix). Additional information on fission products, activation products, and transuranic product content of PWR and CANDU fuel is given in Reference 1.

Table II-2 also shows that the radioactivity and thermal power of spent fuel aged for two years are less than 1% of that for fresh spent fuel. Aging for an additional three years results in further reductions of less than a factor of three. 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 and types of radiation emitted, the need for shielding and cooling decreases more rapidly than the need for isolation.

F.2 Basin Storage

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.

In other cases, it has been possible to ship the fuel assemblies to other reactor sites or to privately owned spent fuel storage basins. The private basins in the U.S. include those at the General Electric (GE) Morris Plant, the Nuclear Fuel Service (NFS) West Valley Plant, and the Allied General (AGNS)
C Barnwell Plant (not currently storing fuel). The capacity of GE, NFS, and AGNS could be increased by densification of storage.

These facilities are described in Volume 2. They have a current capacity of about 500 to 1000 MTU of basin space that
C will become inadequate within a few years, but these facilities can be expanded. As discussed in this report, a capacity of several thousand MTU will be needed by the year 1985. Alternatives that could be developed to meet the needs are described in the remaining parts of this section.

TABLE II-2

Radioactivity and Thermal Power in Spent LWR and CANDU Fuel per MT Uranium Charged to Reactor

	Spent LWR Fuel[a]			*Spent CANDU Fuel*[b]		
Years After Discharge →	*0*	*2*	*5*	*0*	*2*	*5*
Radionuclide Content, curies						
Important Activation Products						
^{14}C[c]	6.6×10^{-1}	6.6×10^{-1}	6.6×10^{-1}	4.6×10^{-1}	4.6×10^{-1}	4.6×10^{-1}
^{55}Fe	2.0×10^{3}	1.2×10^{3}	5.2×10^{2}	2.1×10^{3}	1.3×10^{3}	5.6×10^{2}
^{60}Co	6.3×10^{3}	4.8×10^{3}	3.3×10^{3}	4.1×10^{3}	3.2×10^{3}	2.1×10^{3}
^{63}Ni	5.5×10^{2}	5.5×10^{2}	5.3×10^{2}	4.8×10^{2}	4.8×10^{2}	4.7×10^{2}
^{55}Zr	2.8×10^{4}	1.2×10^{1}	1.0×10^{4}	4.1×10^{2}	1.7×10^{2}	1.4×10^{2}
Total Activation Products	1.4×10^{5}	6.7×10^{3}	4.3×10^{3}	2.1×10^{4}	5.0×10^{1}	3.2×10^{-4}
Important Fission Products						
^{3}H	5.1×10^{2}	4.6×10^{2}	3.9×10^{2}	1.4×10^{2}	1.3×10^{2}	1.0×10^{2}
^{85}Kr	1.1×10^{4}	1.0×10^{4}	8.3×10^{3}	2.7×10^{3}	2.4×10^{3}	2.0×10^{3}
^{90}Sr	7.8×10^{4}	7.5×10^{4}	6.9×10^{4}	1.8×10^{4}	1.7×10^{4}	1.5×10^{4}
^{106}Ru	5.3×10^{5}	1.3×10^{5}	1.7×10^{4}	2.8×10^{5}	7.0×10^{4}	8.8×10^{3}
^{129}I	3.7×10^{-2}	3.7×10^{-2}	3.7×10^{-2}	1.0×10^{-2}	1.0×10^{-2}	1.0×10^{-2}
^{137}Cs	1.1×10^{5}	1.0×10^{5}	9.6×10^{4}	2.8×10^{4}	2.7×10^{4}	2.5×10^{4}
Total Fission Products	1.4×10^{8}	1.2×10^{6}	4.8×10^{5}	1.2×10^{8}	4.7×10^{5}	1.4×10^{5}
Important Transuranium Products						
^{238}Pu	2.7×10^{7}	2.8×10^{7}	2.8×10^{7}	9.1×10^{1}	1.0×10^{2}	1.0×10^{2}
^{239}Pu	3.2×10^{2}	3.2×10^{2}	3.2×10^{2}	1.5×10^{2}	1.6×10^{2}	1.6×10^{2}
^{240}Pu	4.7×10^{2}	4.7×10^{2}	4.7×10^{2}	2.8×10^{2}	2.8×10^{2}	2.8×10^{2}
^{241}Pu	1.0×10^{5}	9.4×10^{4}	8.1×10^{4}	2.8×10^{4}	2.6×10^{4}	2.2×10^{4}
^{241}Am	8.4×10^{1}	4.0×10^{2}	8.0×10^{2}	9.3×10^{0}	9.5×10^{1}	2.1×10^{2}
^{244}Cm	2.2×10^{3}	2.1×10^{3}	1.8×10^{3}	4.9×10^{1}	4.6×10^{1}	4.1×10^{1}
Total Transuranium Products	3.8×10^{7}	1.0×10^{5}	8.7×10^{4}	4.3×10^{7}	2.6×10^{4}	2.3×10^{4}
Thermal Power, Watts	1.6×10^{4}	5.9×10^{3}	2.1×10^{3}	1.4×10^{6}	2.1×10^{3}	4.7×10^{2}

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

b. Calculated with the ORIGEN code for CANDU fuel irradiated to 8200 MWD/MTU at a specific power of 26 MW/MTU.

c. Based on 25 ppm nitrogen (by weight) in fuel.

Several ways of providing additional fuel storage have been proposed (Volume 2). 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 casks) geologic formations, or near-surface caissons. These storage alternatives are compared in Table II-3.

None of the alternatives described in Table II-3 is available today for interim spent fuel storage other than the limited private basin capacity. Interim storage in a geologic repository may become a viable option when a geologic repository becomes available. Use of this same facility for interim storage and later for terminal storage would reduce the amount of future interim storage facilities.

Modular water-cooled basin storage of unpackaged spent fuel was selected as the generic method for interim storage in Volume 2 because it is a proved concept that is acceptable to the NRC. The same type facility is assumed in this volume for the storage of foreign spent fuel in U.S. and foreign facilities.

A schematic representation of the major process steps in an ISFS water basin facility is shown in Figure II-4. Figure II-5 is a plot plan for a generic ISFS* 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.

The water depth in the facility is sufficient to allow vertical unloading of the spent fuel from the casks and at the same time shield the operating personnel from the spent fuel. All spent fuel is handled by remote control under a minimum of 3.5-m (12-ft) of water to shield the operating personnel from the intense radiation emitted from the irradiated fuel. More details about the generic facility and its operations are included in Reference 1 and Volume 2.

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* ISFS — Independent Spent Fuel Storage, i.e., away from reactor.

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.

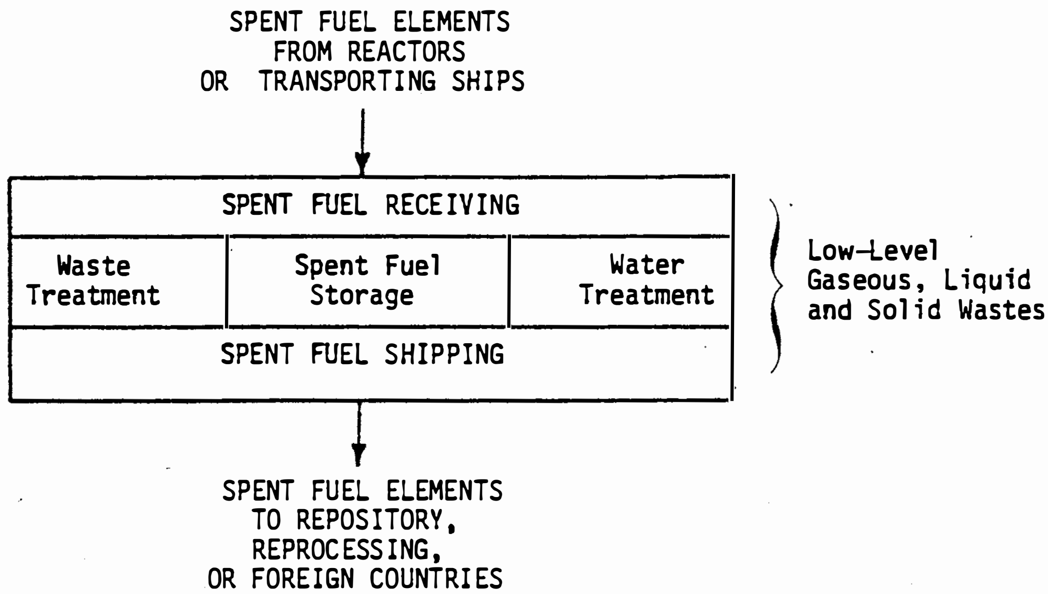


FIGURE II-4. Simplified Schematic of the ISFS Storage Basin Process

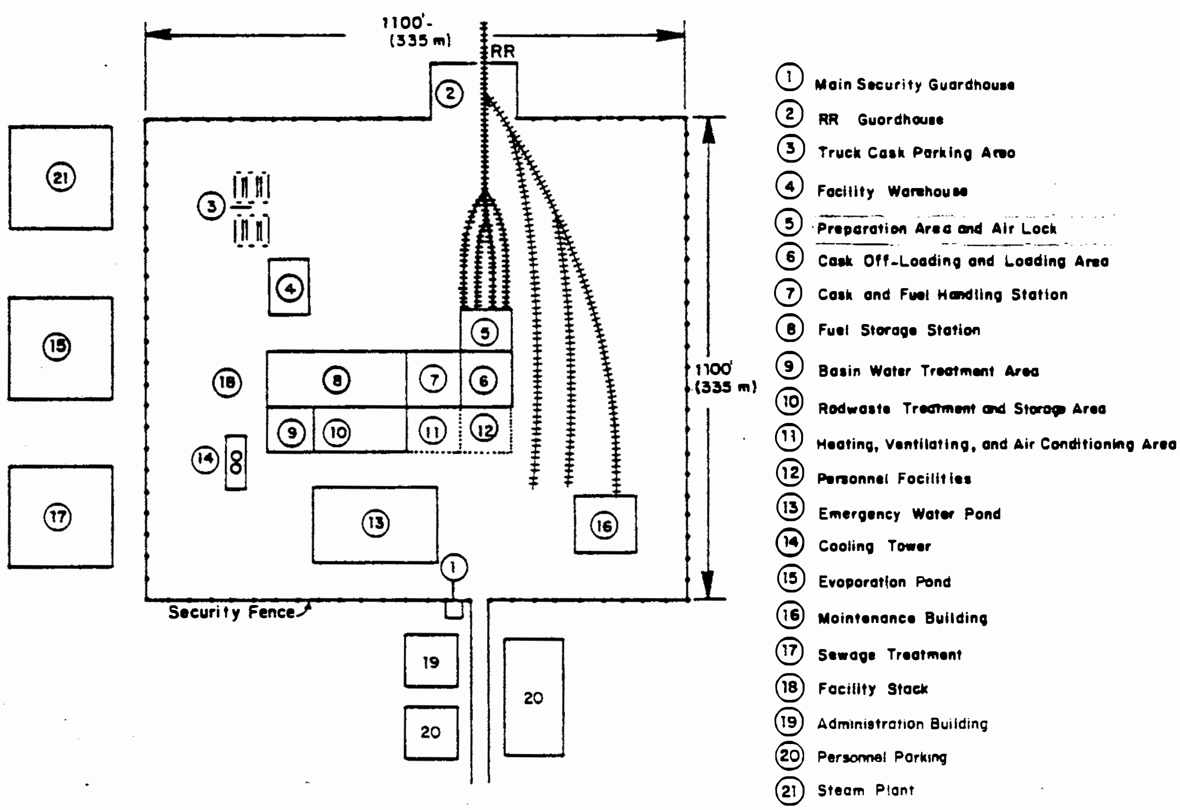


FIGURE II-5. Plot Plan for an ISFS Storage Facility for Unpackaged Spent LWR Fuel

F.3 Disposition Facilities

Facilities for ultimate disposition of the spent fuel are discussed in this volume to furnish the decisionmaker with the C long-term implication of accepting foreign spent fuel. However, the disposition decision is not considered to be a part of Volume 2. Basically, in this volume, disposition is assumed to occur after interim storage of the spent fuel and will consist of either 1) disposal in a geologic repository or 2) reprocessing to recover and reuse the uranium and plutonium content of the spent fuel. In this reprocessing mode, reprocessing waste will be disposed of in a geologic repository. The next two sections describe the geologic repository and the reprocessing and fuel fabrication facilities.

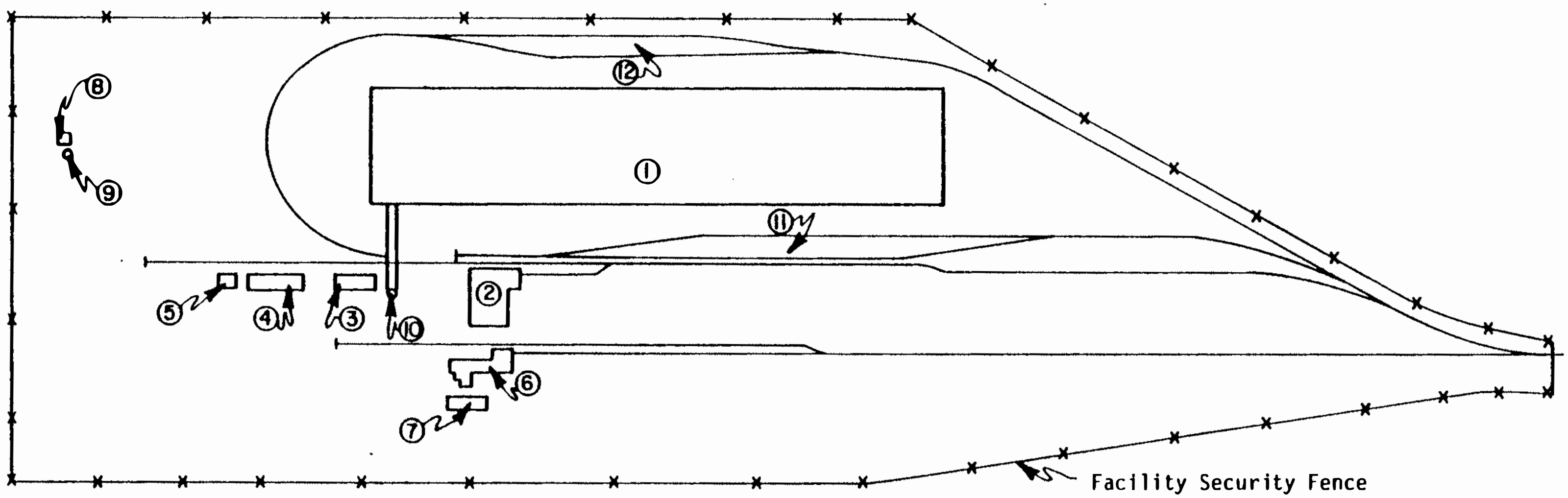
F.3.1 Geologic Disposal Facility

C In this volume, the generic geologic repository for disposal of spent fuel or reprocessing waste is assumed to be constructed in a salt formation. Selection of a salt repository for this environmental analysis does not infer that salt is either the most likely or the optimum alternative for a geologic repository, but C serves only as a reference repository.

Neither alternatives to a geologic repository nor the alternative host materials for geologic repositories are discussed in this volume because the disposition facilities identified in this 6-a volume are to show the effect of accepting the foreign fuel under the Spent Fuel Storage Policy. An EIS[8] entitled the Management of Commercially Generated Radioactive Wastes which was issued in draft for review and comments on April 7, 1979 is in the process of being finalized by DOE to evaluate the environmental impact of options for waste disposal.

The generic geologic repository assumed in this volume is designed to receive, encapsulate, and place spent LWR and CANDU fuel elements, high-level waste, and transuranic (TRU) waste in mined locations 450 to 600 m (1500 to 2000 ft) below the surface.

The waste repository consists of surface facilities for waste receiving and handling, mining support, and general operations support and subsurface facilities for waste handling and storage and mined salt removal. Figure II-6, a facility plot plan, shows the surface facility layout. Figure II-7 shows subsurface facilities. These facilities are described in more detail in DOE-ET-0054.[1]



Legend:

1. Mined Salt Storage Building
2. Canistered Waste Receiving Building
3. Mine Operation Building
4. Warehouse
5. Electrical Substation
6. Low-Level Waste Receiving Building
7. Administration Building
8. Exhaust Ventilation Building
9. Upcast Vent Shaft
10. Men and Material (M&M) Shaft
11. } Storage Tracks with 100-Can Capacity
12. }

FIGURE II-6. Plot Plan for Repository Surface Facilities

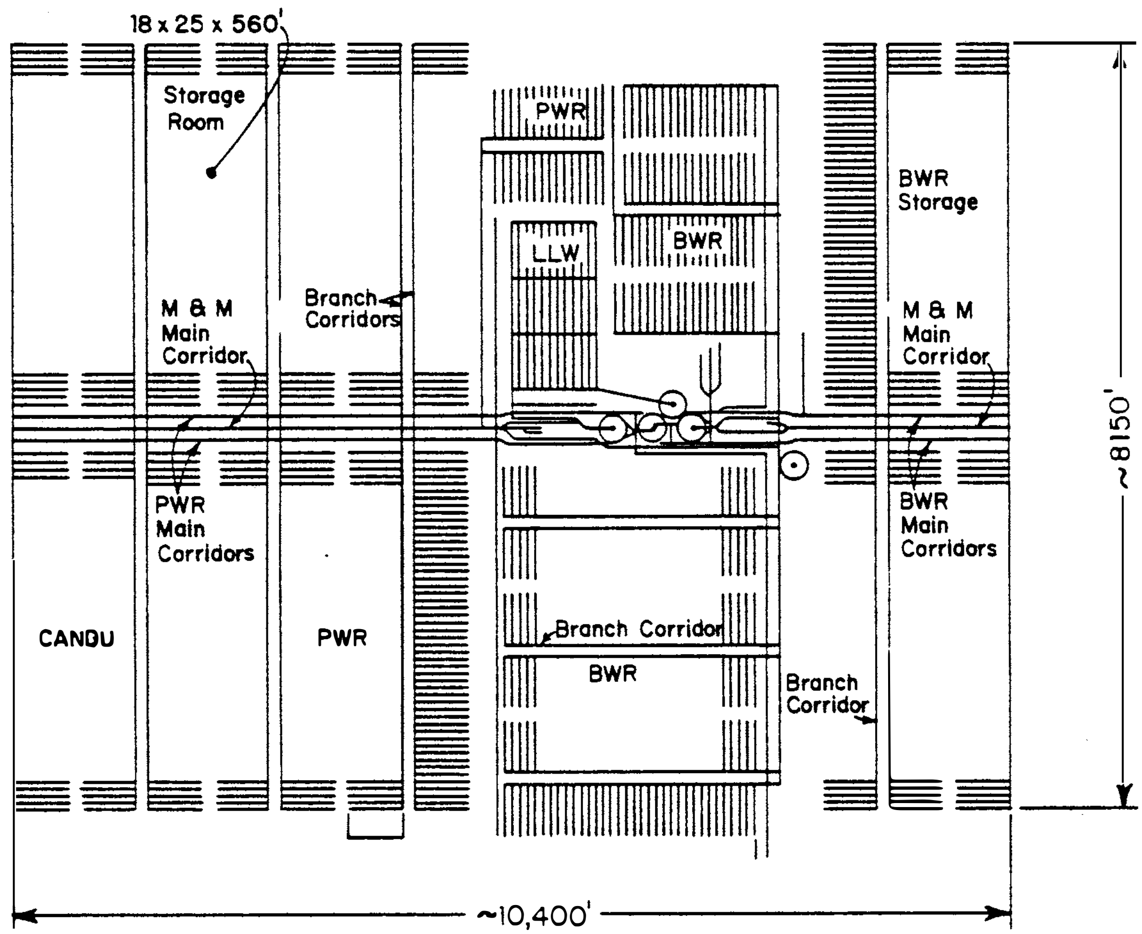


FIGURE II-7. Underground Repository

F.3.2 Reprocessing and Fuel Fabrication (FRP-MOX) Facilities

In this volume, spent fuel reprocessing and fuel fabrication are assumed to take place in a collocated fuel reprocessing-mixed oxide fuel refabrication (FRP-MOX) plant. The conventional Purex process is used in the reprocessing plant to produce separate or combined streams of uranium and plutonium for recycle and waste for disposal. The FRP and MOX plants are assumed to meet the proliferation-resistance and safeguards criteria that are current at the time of startup.

12-1 Proliferation-resistant technology as used in this final EIS describes reprocessing technologies that increase the difficulty of diversion of plutonium and enriched uranium to some as yet undefined level. These technologies are being assessed as part of the International Nuclear Fuel Cycle Evaluation (INFCE) and Nonproliferation Alternative Systems Assessment Programs (NASAP). The FRP-MOX facilities considered in this EIS in Cases E, F-1, and F-2 will meet all requirements in effect at the time reprocessing begins.

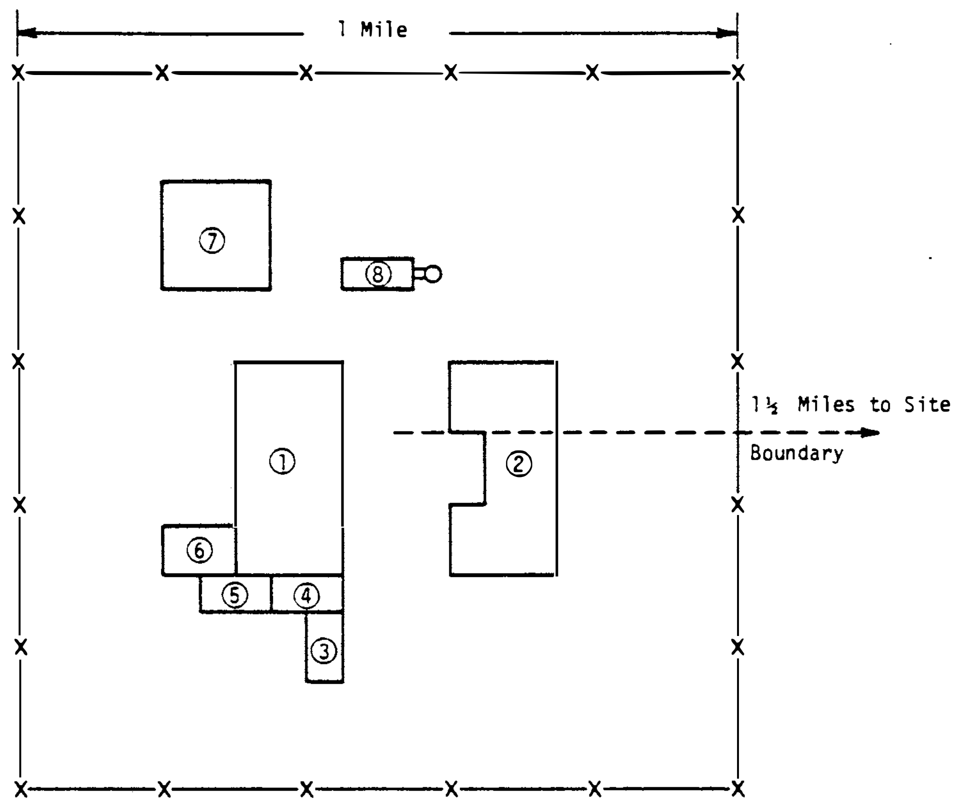
The FRP-MOX facilities assumed to be used for reprocessing foreign fuels during the next few years employ the conventional Purex process. The environmental effects of this FRP-MOX facility developed in ERDA-77-75[9] are used as the basis for the analysis in this volume. However, the ongoing assessment programs of alternative fuel cycles with improved proliferation resistance are assumed to continue, and to result in a modification of the Purex process and reduce proliferation risks by the mid-1990s. The alternatives that are currently under study include 1) partial decontamination of the fission products, 2) spiking or denaturing, or 3) preirradiation. Each of these alternatives is designed to result in the final product streams being radioactive, thus, requiring heavy shielding to make the diversion of the enriched uranium or plutonium much more difficult. To enable assessment of environmental effects of the FRP-MOX, a modification of the Purex process is assumed to be used in the mid-1990s to produce a uranium stream and a combined stream of plutonium and uranium (coprocessing) that also includes a strong gamma emitter (spiking). The environmental effects of this proliferation-resistant FRP-MOX facility have not been analyzed, but the improved proliferation resistance and safeguards features are assumed not to increase the environmental impacts over previously analyzed FRP-MOX plants developed in ERDA-77-75.[9]

The generic FRP-MOX operations are assumed to be located at the same site, within a fenced area of about 2430 hectares (6000 acres).[9,10] This area permits a 2.4-km (1.5-mi) buffer zone around the plants. A sample layout of the site is shown in

Figure II-8. The principal operating components of the site are

- Fuel Receiving and Storage Facility
- Fuel Reprocessing Facility
- Uranium Conversion Facility (UF_6 Plant)
- Plutonium Conversion and Mixed Oxide Fuel Fabrication Facility
- Waste Handling Facility
- Ventilation Filtration Facility and Exhaust Stack

C These components are described in DOE-ET-0054[1] along with the methodology assumed for determining environmental effects.



Legend

① Fuel Rep ocessing Plant
② MOX Fuel Fabrication Plant
③ Fuel Receiving Facility
④ Fuel Storage Facility
⑤ Waste Storage Facility
⑥ Waste Handling Facility
⑦ UF_6 Plant
⑧ Ventilation Filtration and Stack

FIGURE II-8. Plot Plan for Collocated Fuel Reprocessing and MOX Plant

F.3.3 Transportation Systems

Existing designs of truck, rail, and marine cask systems can provide transportation for foreign and domestic fuel. Sufficient shipping casks for spent fuel and reprocessing wastes
9-b are not now available; but in this volume, cask availability is assumed not to delay implementation of the spent fuel program. Foreign casks are assumed to be used to ship foreign fuel to the U.S. (government facilities) and for any return shipment. Spent fuel casks of these types are currently being fabricated in Europe and Asia. In this volume, U.S. casks are also assumed to be used for other shipments of foreign spent fuel within the United States. U.S. cask fabrication and availability are described in Volume 2. Additional discussion of cask availability is contained in Section VIII of this volume. Foreign reactors
C are assumed to have facilities for overweight truck casks or rail casks. The assumption is made that 80% of the foreign LWR fuel is transported from foreign docks to U.S. facilities in rail casks and 20% of foreign LWR fuel is shipped in overweight truck casks. All CANDU fuel is assumed to be shipped in rail casks.

Massive, heavily shielded shipping casks designed for land transportation of spent fuel from current generation of LWRs have been licensed for both truck and rail systems. Either PWR or BWR fuel can be shipped in most of the spent fuel casks with different fuel baskets; however, some casks are designed only for a particular fuel type. Large casks designed specifically for
C CANDU fuel do not exist, but conceptual designs for baskets for storage of CANDU fuel in ISFS facilities are compatible with the NLI 10/24 cask, for example. Other spent fuel shipping casks for CANDU will be constructed as needed. A more detailed description of casks and land transportation systems can be found in Reference 1 and Volume 2.

C In this volume, spent fuel is assumed to be transported from foreign ports to U.S. ports and any return shipments will be by cargo ship of the 20,000 dead weight ton class. Such ships carry a cargo of 7,000 tons and can readily include spent fuel casks as part of their cargo if the casks are placed on load spreading devices. Many regularly scheduled cargo ships of this type also have roll-on, roll-off facilities, and these could be used for overweight truck casks mounted on trailers. Rail casks built in the U.S. and Europe that could be shipped by sea on regularly scheduled cargo ships are discussed in DOE-ET-0054.[1]

C The spent fuel is transported from the U.S. port to an ISFS basin facility or geologic repository by U.S. commercial carriers hired by the broker or agency responsible for the international transfer. Therefore, U.S. regulations apply to shipments of foreign fuel shipments only within the U.S.

F.3.4 International Transport Regulations

9-d Major regulations for transporting radioactive materials internationally are developed and controlled by the IAEA.[11] These regulations are adopted by almost all international organizations concerned with transportation, and IAEA members use them as the basis of their national regulations.

The IAEA packaging and shipping requirements for transporting radioactive materials are approximately the same as the U.S. Federal regulations and are a function of quantity, type, and fissile characteristics of the radionuclides being shipped. Both U.S. and other nations which accept IAEA regulations mutually accept and allow shipment of certified packages, in both the U.S. and abroad.

The Office of Hazardous Materials (an office under the U.S. Department of Transportation - DOT) requires that foreign shipments into the U.S. provide comparable safety to that of domestic shipments. DOT regulations (49 CFR 173.393b) require the foreign shipper to notify the Office of Hazardous Materials of impending shipments to the U.S. and also to submit a copy of a valid foreign competent authority certificate for the package. If review of these items indicate adequate safety will be ensured, DOT authorizes the shipment. DOT may request that NRC review the adequacy of the proposed package. The U.S. transportation regulations, discussed in Reference 1 and Volume 2 of this final EIS, will apply to the U.S. carriers who will transport the foreign spent fuel in the U.S.

In addition to IAEA regulations,[11] a code of practice for maritime transport of nuclear materials is included in the Maritime Dangerous Goods Code written by the Inter-Governmental Marine Consultative Organization (IMCO).[12] The IMCO code is designed to ensure safety of ship, cargo, persons, and the environment. This code is not legally binding but has been adopted and implemented by national legislation in many countries.

11-a F.3.5 Institutional Issues

11-b Operations dealing with transportation, storage, and disposition of spent fuel raise a number of institutional issues involving: 1) legal questions, 2) regulatory and licensing requirements, and 3) international agreements, arrangements, and understandings. Resolution of these institutional issues is complex because they involve interaction among industry, government, and social institutions.

Legal

New agreements between participants would be required if international storage of spent fuel were to occur. These storage agreements could involve numerous complex legal issues. Existing national laws may conflict with agreements expected to be reached in negotiations for international storage of spent fuel. If the agreements are intergovernmental, such as a treaty, ratification of the agreement by the legislative body of individual nations might resolve conflicts with the agreement provisions. Otherwise, special legislation by the participant nation would be required.

The participants, including intergovernmental agencies such as IAEA, will probably be defined and their legal right and duties documented in the agreements. Provisions for the addition and withdrawal of participants will also probably be included.

U.S. maritime law is currently unclear as to the liability of the carrier for incidents involving nuclear materials which occur outside the territorial limits of the U.S. and cause effects within the U.S. As indicated in Reference 13, traditionally, the prevailing rule of maritime law is that liability is based upon fault and limited to the value of the vessel and cargo after the cause of loss has taken place. In the absence of a controlling convention or other form of international legal consideration, the law governing the liability in transnational transportation will be determined by general principles of conflicts of laws. International conferences on maritime matters tend to recommend rules for adoption by governments without embodying them in a convention. As a result, maritime law remains national law, and it is likely that the controlling law will be that of the nation which suffers the damage.[13]

Regulatory Licensing and Requirements

Nations that may participate in international storage of spent fuel regulate most of their own nuclear activities internally. Regulations typically consider public health and safety, 11-a 11-b environmental impacts, physical security, safeguards, accountability, transportation, import and export, indemnity and liability, etc. Licenses are usually issued by the competent government authority according to its established requirements to conduct nuclear-related activities. Although uniform international guidelines have been adopted for some of these areas including liability to nonparticipating parties, safeguards, and transportation restrictions, the detailed licensing requirements may differ substantially from country to country.

In most countries, transportation is regulated by a designated governmental authority or "competent authority," and their laws are based upon guidelines issued by the IAEA entitled "Regulations for the Safe Transport of Radioactive Materials," Safety Series No. 6 (1973).[11] Shipments at sea are governed by guidelines in the International Maritime Dangerous Goods Code[12] issued by the Inter-Governmental Maritime Consultative Organization.

9-a U.S. regulations also apply to the U.S. carriers that transport foreign spent fuel within the U.S. as discussed in Appendix C of Volume 2 of this final EIS. Routing from U.S. ports to interim storage or disposition facilities will be governed by NRC, DOT, state, and local regulations and ordinances. The transfer of spent fuel from ships to land transportation systems at U.S. docks and transport of foreign spent fuel through port cities and within the U.S. will be analyzed in a subsequent AFR-EIS if the Spent Fuel Storage Policy is implemented as discussed in the "Foreword."

11-a 11-b <u>International Agreements, Arrangements, and Understandings</u>

The international agreements, arrangements, and understandings for international storage of spent fuel would be written to define precisely the function, duties, and responsibilities of each participant and the nations hosting storage, disposal, and reprocessing facilities. The operating entity and its management form would be established for each facility. Jurisdictional delineations for regulatory and legal aspects and financial responsibilities, including liability to nonparticipating parties, probably would be specified in agreements and memoranda of understanding among participants. Safeguard and nonproliferation obligations must also be precisely defined. The Nonproliferation Treaty (NPT) and subsequent bilateral treaties between NPT nations and IAEA already impose safeguard obligations on some participants. The obligations of participants who have not signed the NPT would be established.

Facility inspection procedures, such as standards and methods, would be established. For example, IAEA's established safeguards system might be adopted to regulate accounting for nuclear

11-a materials. Physical security requirements would be established
11-b by user nations participating in the international storage program.

G. Relationship to Other Federal Programs

A number of other Federal programs may modify the implementation of the U.S. Policy on Spent Fuel Storage. The programs include:

- Nonproliferation Alternative Systems Assessment Program (NASAP)
- International Nuclear Fuel Cycle Evaluation (INFCE)
- DOE Converter Fuel Cycle Technology Program
- National Waste Terminal Storage (NWTS)
- Waste Isolation Pilot Plant (WIPP)
- EPA and NRC Programs

The relationship of these programs and the Spent Fuel Storage Policy are discussed in the following paragraphs.

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 with the objective of defining fuel cycles that have the most potential for reducing the risks of nuclear weapon proliferation while still providing the benefits associated with 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 under the INFCE and NASAP programs that reduce the risks of nuclear weapon proliferation.

Department of Energy Converter Fuel Cycle Technology Programs

These ongoing programs will provide technical information to NASAP and INFCE on advanced fuel cycles having proliferation-resistance 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 U.S. commercial nuclear waste or spent fuel in geologic formation(s). This program interfaces with the disposition of U.S. spent fuel as described in Volume 2. If the foreign fuel is received into the U.S. under the Spent Fuel Storage Policy, comparable disposal may be required; if so, it would be disposed of in the geologic repository. 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 may be classified as waste and to retrievable storage of spent fuel that may later be reprocessed.

Waste Isolation Pilot Plant (WIPP)

C The principal mission of WIPP was ultimate disposal of transuranic (TRU) waste from the national defense program.[14] The President recently stated[15] 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."

EPA and NRC Programs

C 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 impact statement that evaluates "at reactor" and "independent spent fuel" storage and supporting operations. A finding of the NRC Final GEIS (NUREG-0575)[16] is that storage of LWR fuels in water pools, whether at reactor sites or at independent spent fuel storage sites, has an insignificant impact on the environment. The NRC GEIS indicates also that, technically, "at reactor" storage can be greatly expanded. Even though, with the assumed substantial expansion of discharge basin storage capacity, the "away-from-reactor" storage requirements per calendar year would be reduced, they would not be eliminated.

H. Environmental Controls and Monitoring

Environmental monitoring and controls for U.S. facilities are described in Volume 2 in Section II H. These same programs and controls will apply to U.S. facilities receiving, processing, or storing foreign fuel. Monitoring and/or controls at foreign facilities may not meet U.S. regulations, but appropriate IAEA monitoring and controls will probably apply.

I. Safeguards

The safeguards applicable to U.S. facilities are described in Volume 2. These safeguards will also apply to U.S. transportation operations and facilities, receiving, processing, or
C storing foreign fuels. Applicable portions of 10 CFR 73[17] provide the current requirements for these facilities. These requirements specify the degree of protection required by the facilities and personnel, control to assure that the material is always in its designated location, and predefined response to
10-a threats on this material. A recent revision of 10 CFR 73[18] requires physical protection of spent fuel during transportation to safeguard against theft or sabotage.

C Foreign facilities discussed in this volume are subject to different, and, in some cases, less stringent material accountability and physical protection controls than similar U.S. facilities. Foreign facilities would, by and large, be subject to their own national system of safeguards and security (to protect against subnational threats) and IAEA safeguards as an overlay to verify material accountancy by the state.

One of the key objectives of the Spent Fuel Storage Policy is to provide consistently high standards of safeguards and security protection under U.S. auspices and, therefore, reduce the somewhat higher risk of less stringent foreign safeguards systems not under direct U.S. control.

The safeguards considerations are discussed further in Section IV of this volume.

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17. U.S. Code of Federal Regulations, Title 10. Part 73 (10 CFR 73), U.S. Government Printing Office, Washington, DC (1979).

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III. ALTERNATIVES AND THEIR ENVIRONMENTAL EFFECTS

A. Introduction

A.1 Description of Cases Analyzed

The President's announcement in October 1977 of the U.S. Spent Fuel Storage Policy included an offer for the U.S. to accept limited quantities of foreign spent power reactor fuel for storage. Such action would further nonproliferation objectives. The amounts of foreign spent fuel that may be involved in implementing this program are discussed in detail in Section II D.

Nine cases spanning the reasonable options associated with implementing or not implementing the policy were identified for assuming initial U.S. geologic repository operations begin by the year 1995. The major environmental effects of these nine cases are presented in this section. The time period covered is that associated with operations carried out on the foreign spent fuel available through the year 2000.

The nine cases analyzed in this section are those which appeared in the draft version of the EIS. Environmental analysis of two additional cases based on Option 2 fuel schedule and a delayed startup of the first U.S. geologic repository to the year 2010 are presented in Appendix A. Only the effects of interim operations were analyzed for these two new cases whereas the analyses for the previous nine cases included interim and disposition operations. The new analysis from Appendix A was included to show the comparison of effects of implementing the U.S. Spent Fuel Policy for storage of foreign fuel with not implementing this policy if the U.S. geologic repository is delayed beyond the year 2000.

Table III-1 gives the definitions for each of the nine cases discussed in this section. The proposed operations that would be involved with the foreign fuel in each of the nine cases are shown in Table III-2. In addition, the assumed operations associated with U.S. spent fuel are also shown in Table III-1 because the offer to accept foreign fuel for storage in the U.S. is part of a much larger proposed program involving storage by the U.S. Government of spent fuel from domestic power reactors (Volume 2).

The quantity of foreign spent fuel projected to be shipped to the U.S. in the nine cases ranges from 0 to 19% (0 to 13,600 MTU) of the estimated quantity of U.S. spent fuel assumed to become available through the year 2000. Because the foreign spent fuel represents a modest fraction of domestic fuel, the environmental effects of the foreign spent fuel shipped to the

U.S. are determined incrementally. The Option 3 fuel schedule* is assumed for Cases A through F-2; the Option 2 fuel schedule** is assumed for Case G; and the Option 1 fuel schedule† for Case H.

TABLE III-1

Case Definitions

Proposed Action in Foreign Countries[a]	*Assumed Action in United States*
Case A	
The foreign countries are responsible for their spent fuel. It is expected that they will make arrangements for interim storage of spent fuel, until FRP-MOX plants[b] and/or geologic repositories are available. Ultimately, it is assumed that the foreign countries either (1) reprocess the spent fuel, recycle the plutonium and uranium and dispose of the reprocessing waste in foreign geologic repositories or (2) dispose of the spent fuel in foreign geologic repositories.	The U.S. Government provides a geologic repository in the U.S. for disposal of U.S. spent fuel only. Utilities are responsible for storage of their spent fuel until the geologic repository becomes available in the year 1985, at which time storage of spent fuel will begin in the repository. A decision is made in the year 1990 not to reprocess U.S. spent fuel, and the U.S. spent fuel is then disposed of in the geologic repository.
Case B	
U.S. supports multinational storage arrangements outside the U.S. to be owned or operated under U.S. or under international auspices. Formal arrangements could take the form of a multinational ISFS[c] facility under specific country or multiple country ownership and/or operation, or under the auspices of an existing international organization, e.g., IAEA. Thus, interim storage of foreign spent fuel could be at a location outside the country of origin. The siting of such facilities would be by international agreement, but in all cases they would be located outside sensitive regions. U.S. assistance to such arrangements would be contingent upon the degree to which they contributed to this nation's nonproliferation objectives. Depending upon the circumstances, the U.S. might be a direct participant or could limit its role to providing technical and/or financial assistance. Ultimately, it is assumed that the foreign countries either (1) reprocess the spent fuel, recycle the plutonium and uranium, and dispose of the reprocessing waste in foreign geologic repositories or (2) dispose of the spent fuel in foreign geologic repositories.	The U.S. Government provides a geologic repository in the U.S. for disposal of U.S. spent fuel only. Utilities are responsible for storage of their spent fuel until the geologic repository becomes available in the year 1985, at which time storage of spent fuel will begin in the repository. A decision is made in the year 1990 not to reprocess U.S. spent fuel, and the U.S. spent fuel is then disposed of in the geologic repository.

a. As detailed in Section II-D, three different levels of foreign spent fuel (Options 1, 2, and 3 fuel schedules) are identified in this study of the U.S. offer to store foreign spent fuel.

The Option 1 foreign spent fuel schedule includes fuel from countries inside sensitive regions. Acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

The Option 2 foreign spent fuel schedule includes the Option 1 fuel level and in addition, acceptance of spent fuel from a limited number of other countries with spent fuel storage problems (from a nonproliferation standpoint). Acceptance of fuel by the U.S. will be considered on a case-by-case basis.

The Option 3 foreign spent fuel schedule includes the Option 2 fuel level and in addition, acceptance of some of the spent fuel from a larger number of non-nuclear-weapons states. Again, acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

In Cases A through F-2, the Option 3 fuel schedule is assumed (about 13,600 MTU).
In Case G, the Option 2 fuel schedule is assumed (about 4350 MTU).
In Case H, the Option 3 fuel schedule is assumed (about 2160 MTU).

b. FRP-MOX Plant — fuel reprocessing-mixed oxide fuel fabrication plant.

c. ISFS — Independent Spent Fuel Storage (away-from-reactor storage).

* The Option 3 foreign spent fuel schedule includes the Option 2 fuel level and in addition, acceptance of some of the spent fuel from a larger number of non-nuclear-weapons states. Again, acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

** The Option 2 foreign spent fuel schedule includes the Option 1 fuel level and in addition, acceptance of spent fuel from a limited number of other countries with spent fuel storage problems (from a nonproliferation standpoint). Acceptance of fuel by the U.S. will be considered on a case-by-case basis.

† The Option 1 foreign spent fuel schedule includes fuel from countries inside sensitive regions. Acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

TABLE III-1, Case Definitions (Continued)

Proposed Action in Foreign Countries[a]	*Assumed Action in United States*
Case C	
U.S. supports national storage arrangements abroad on a bilateral basis. Eligible countries would be located outside sensitive regions and would be financially capable of supporting an expanded storage program once initial U.S. assistance terminated. Decisions to offer U.S. assistance would be made on a case-by-case basis. In each instance, cooperative efforts would offer nonproliferation benefits to U.S. policy. The assistance could take the following forms: assistance in increasing the density of existing onsite reactor storage pools through reracking and the installation of neutron-absorbing racks or assistance in the construction of ISFS basin facilities. Ultimately, it is assumed that the foreign countries either (1) reprocess the spent fuel, recycle the plutonium and uranium, and dispose of reprocessing waste in foreign geologic repositories or (2) dispose of the spent fuel in foreign geologic repositories.	The U.S. Government provides a geologic repository in the U.S. for disposal of U.S. spent fuel only. Utilities are responsible for storage of their spent fuel until the geologic repository becomes available in the year 1985, at which time storage of spent fuel will begin in the repository. A decision is made in the year 1990 not to reprocess U.S. spent fuel, and the U.S. spent fuel is then disposed of in the geologic repository.
Case D	
Foreign spent fuel is shipped to the U.S. for storage.	The U.S. Government provides ISFS facilities and a geologic repository for storage of U.S. and foreign spent fuel. The geologic repository becomes available in the year 1985, at which time storage of spent fuel will begin in the repository. A decision is made in the year 1990 not to reprocess the U.S. and foreign spent fuel and both are then disposed of in the geologic repository. The environmental effects are also presented, assuming the geologic repository is delayed ten years (becomes available in the year 1995).

a. As detailed in Section II-D, three different levels of foreign spent fuel (Options 1, 2, and 3 fuel schedules) are identified in this study of the U.S. offer to store foreign spent fuel.

The Option 1 foreign spent fuel schedule includes fuel from countries inside sensitive regions. Acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

The Option 2 foreign spent fuel schedule includes the Option 1 fuel level and in addition, acceptance of spent fuel from a limited number of other countries with spent fuel storage problems (from a nonproliferation standpoint). Acceptance of fuel by the U.S. will be considered on a case-by-case basis.

The Option 3 foreign spent fuel schedule includes the Option 2 fuel level and in addition, acceptance of some of the spent fuel from a larger number of non-nuclear-weapons states. Again, acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

In Cases A through F-2, the Option 3 fuel schedule is assumed (about 13,600 MTU).
In Case G, the Option 2 fuel schedule is assumed (about 4350 MTU).
In Case H, the Option 3 fuel schedule is assumed (about 2160 MTU).

TABLE III-1, Case Definitions (Continued)

Proposed Action in Foreign Countries[a]	*Assumed Action in United States*
Case E	
Foreign spent fuel is shipped to the U.S. for storage in U.S. Government ISFS facilities and a geologic repository. After a decision is made in the year 1990 to reprocess the U.S. and foreign fuel, the foreign fuel is returned. The foreign countries arrange for reprocessing and refabrication facility services that meet the nonproliferation objectives of the U.S. The location at which the foreign spent fuel is reprocessed and the recovered plutonium and uranium fabricated into fuel assemblies would probably be in a multinational facility under specific country or multiple country ownership and/or operation, or under the auspices of an existing international organization, e.g., IAEA. The return of foreign spent fuel will be contingent upon acceptable nonproliferation safeguards to restrict the locations of sensitive facilities and activities, and to control the location of sensitive materials. Sensitive facilities and unirradiated fuel containing plutonium would not be permitted in countries located inside sensitive regions. These countries could negotiate compensation for any net fuel value of the plutonium and uranium recovered from their spent fuel. After the foreign fuel is reprocessed, and the plutonium and uranium fabricated into fuel assemblies, the fuel assemblies will be irradiated in foreign power reactors. The reprocessing waste is disposed of in a foreign geologic repository.	The U.S. Government provides ISFS facilities and a geologic repository for storage of U.S. and foreign spent fuel. The geologic repository becomes available in the year 1985, at which time storage of spent fuel will begin in the repository. A decision is made in the year 1990 to reprocess. The U.S. spent fuel is reprocessed in the U.S.; the plutonium and uranium is recycled; and the reprocessing waste is disposed of in the U.S. geologic repository. The foreign fuel is returned for reprocessing in foreign countries (as discussed in the left column). A decision to reprocess spent fuel would require that adequate safeguards be available to meet the nonproliferation objectives of the U.S.
Case F-1	
Foreign spent fuel is shipped to the U.S. for storage.	The U.S. Government provides ISFS facilities and a geologic repository for storage of U.S. and foreign spent fuel. The geologic repository becomes available in the year 1985, at which time storage of spent fuel will begin in the repository. A decision is made in the year 1990 that the U.S. will reprocess both the U.S. and foreign fuel and recycle the plutonium and uranium from both the U.S. and foreign spent fuel in U.S. power reactors. A decision to reprocess spent fuel would require that adequate safeguards be available to meet the nonproliferation objectives of the U.S. The reprocessing waste is disposed of in a geologic repository. In all cases involving acceptance of foreign fuel for storage, the U.S. assumes full, irrevocable title to the foreign spent fuel. In this case, the U.S. reprocesses the foreign fuel and recycles the recovered plutonium and uranium in U.S. power reactors. Any residual fuel value of the foreign fuel would be the subject of negotiations.

a. As detailed in Section II-D, three different levels of foreign spent fuel (Options 1, 2, and 3 fuel schedules) are identified in this study of the U.S. offer to store foreign spent fuel.

The Option 1 foreign spent fuel schedule includes fuel from countries inside sensitive regions. Acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

The Option 2 foreign spent fuel schedule includes the Option 1 fuel level and in addition, acceptance of spent fuel from a limited number of other countries with spent fuel storage problems (from a nonproliferation standpoint). Acceptance of fuel by the U.S. will be considered on a case-by-case basis.

The Option 3 foreign spent fuel schedule includes the Option 2 fuel level and in addition, acceptance of some of the spent fuel from a larger number of non-nuclear-weapons states. Again, acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

In Cases A through F-2, the Option 3 fuel schedule is assumed (about 13,600 MTU).
In Case G, the Option 2 fuel schedule is assumed (about 4350 MTU).
In Case H, the Option 3 fuel schedule is assumed (about 2160 MTU).

TABLE III-1, Case Definitions (Continued)

Proposed Action in Foreign Countries[a]	*Assumed Action in United States*
Case F-2	
Foreign spent fuel is shipped to the U.S. for storage in U.S. Government ISFS facilities and a geologic repository. After a decision is made in the year 1990 to reprocess the U.S. and foreign spent fuel, the plutonium and uranium in the foreign fuel is returned to foreign countries. The return of the plutonium and uranium recovered in the U.S. to the foreign countries of origin for recycle in their power reactors will be contingent upon demonstration of safeguards acceptable to meet the nonproliferation objectives of the U.S. Unirradiated fuel containing plutonium would not be returned to countries located inside sensitive regions. These countries could negotiate compensation for any net value of the plutonium and uranium recovered from their spent fuel.	The U.S. Government provides ISFS facilities and a geologic repository for storage of U.S. and foreign spent fuel. The geologic repository becomes available in the year 1985, at which time storage of spent fuel will begin in the repository. A decision is made in the year 1990 that the U.S. will reprocess both the U.S. and foreign spent fuel and recycle the plutonium and uranium from the U.S. spent fuel in U.S. power reactors. The plutonium and uranium recovered from the foreign spent fuel will be returned. The reprocessing waste is disposed of in a geologic repository in the U.S. A decision to reprocess spent fuel would require that adequate safeguards be available to meet the nonproliferation objectives of the U.S.
Case G	
	This case is the same as Case D except that the quantity of foreign spent fuel shipped to the United States is lower.[a]
Case H	
	This case is the same as Cases D and G except that the quantity of foreign spent fuel shipped is lower than in Cases D and G.[a]

a. As detailed in Section II-D, three different levels of foreign spent fuel (Options 1, 2, and 3 fuel schedules) are identified in this study of the U.S. offer to store foreign spent fuel.

The Option 1 foreign spent fuel schedule includes fuel from countries inside sensitive regions. Acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

The Option 2 foreign spent fuel schedule includes the Option 1 fuel level and in addition, acceptance of spent fuel from a limited number of other countries with spent fuel storage problems (from a nonproliferation standpoint). Acceptance of fuel by the U.S. will be considered on a case-by-case basis.

The Option 3 foreign spent fuel schedule includes the Option 2 fuel level and in addition, acceptance of some of the spent fuel from a larger number of non-nuclear-weapons states. Again, acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

In Cases A through F-2, the Option 3 fuel schedule is assumed (about 13,600 MTU).
In Case G, the Option 2 fuel schedule is assumed (about 4350 MTU).
In Case H, the Option 3 fuel schedule is assumed (about 2160 MTU).

TABLE III-2

Summary of Operations Involved in Cases

Case	*A*[a]		*B*[a]		*C*[a]		*D*	*E*	*F-1*	*F-2*	*G*	*H*
Foreign Spent Fuel *Fuel Schedule Option*[b]	3		3		3		3	3	3	3	2	1
Retained in Foreign Countries	●	●	●	●	●	●						
Interim Storage in Foreign Countries Without U.S. Support	●	●										
U.S. Supports Interim Storage in Countries of Origin Except Those Located in Sensitive Regions					●	●						
U.S. Supports Interim Storage in Multinational Storage Facilities Located in Countries Outside Sensitive Regions			●	●								
Shipped to U.S. for Storage							●	●	●	●	●	●
Returned to Foreign Countries								●				
Reprocessed in U.S.[c]									●	●		
Reprocessed in Foreign Countries[d]	●		●		●			●				
Separated Plutonium and Uranium Recycled in U.S.									●			
Separated Plutonium and Uranium Recycled in Foreign Countries	●		●		●			●		●		
Disposed of as Waste in U.S. Geologic Repository[e]							●				●	●
Spent Fuel Disposed of as Waste in Foreign Geologic Repositories		●		●		●						

a. In Cases A, B, and C, disposition of the spent fuel by reprocessing and by disposal in a geologic repository is considered. In the first column, the fuel is assumed to be reprocessed. In the second column, the spent fuel is assumed to be disposed of as waste in a geologic repository.

b. As detailed in Section II D, three different levels of foreign spent fuel (Options 1, 2, and 3) are identified in this study of the U.S. offer to store foreign spent fuel.

The Option 1 foreign spent fuel schedule includes fuel from countries inside sensitive regions. Acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

The Option 2 foreign spent fuel schedule includes the Option 1 fuel level and in addition, acceptance of spent fuel from a limited number of other countries with spent fuel storage problems (from a nonproliferation standpoint). Acceptance of fuel by the U.S. will be considered on a case-by-case basis.

The Option 3 foreign spent fuel schedule includes the Option 2 fuel level and in addition, acceptance of some of the spent fuel from a larger number of non-nuclear-weapons states. Again, acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

c. Reprocessing waste is disposed of in U.S. geologic repository.

d. Reprocessing waste is disposed of in foreign geologic repositories.

e. U.S. geologic repository is assumed to be available for initial use in the year 1985 in all cases. Cases D, G, and H are also analyzed, assuming the repository is delayed ten years to the year 1995.

C A foldout at the back of the report includes the tabulations in Table III-2 to provide easy reference to the cases as the reader proceeds through this volume.

A.2 Methodology

The environmental effects from operations with foreign spent fuel are presented in a format that provides input into the decisions to accept foreign spent fuel as a portion of the U.S. Spent Fuel Storage Policy. Therefore, the methodology in this volume focuses on the incremental effects of acceptance of foreign fuel in the U.S. This increment is determined as follows:

1) The environmental effects are assessed for activities involving the foreign spent fuel that take place outside the U.S.

2) The effects are assessed for activities in the U.S. involving both foreign and domestic fuels.

3) The portion of the environmental effects for activities in the U.S. attributed to foreign fuel is determined on the basis of the proportionate amount of foreign fuel associated with that activity.

4) The sum of 1) and 3) represents the increment related to the foreign fuel.

The methodology used in calculating the environmental effects for the cases analyzed in this report is the same as that used in Volume 2, Storage of U.S. Spent Power Reactor Fuel and is described in more detail in DOE-ET-0054.[1]

A.3 Environmental Impact Considerations

The major environmental impacts presented for each case in this section include the nonproliferation effects, population dose commitments, occupational exposures, radiological health effects,* and deaths resulting from accidents.

* The radiological health effects expected to result from population and occupational exposure were calculated by using the linear dose-effect relationships derived from the BEIR[2] Report by the EPA.[3,4] They include somatic and genetic effects. No threshold dose is assumed for health effects. A detailed discussion of the calculation of health effects is given in DOE-ET-0054[1] and Volume 2 of this final EIS.

Resources that are committed in an irreversible and irretrievable manner by the actions considered in this section are modest and are given in Section VI of this report.

The environmental impacts of nonradiological releases from transportation and interim storage of spent fuel (e.g., thermal effluents, releases from combustion of fossil fuel, liquid and chemical effluents, etc.) are not specifically tabulated in Volume 3. These effects are assessed in Volume 2 (Storage of U.S. Spent Power Reactor Fuel) where they are found to be small and well within accepted limits. The increment resulting from storage of relatively small amounts of foreign fuel would not add significantly to the impacts.

Environmental impacts are presented for the operations involved with interim storage of foreign spent fuel and for the operations associated with disposition of this fuel. In this volume, disposition activities are either 1) fuel reprocessing (with disposal of reprocessing waste in geologic repositories), or 2) disposing of the spent fuel in geologic repositories. The environmental effects resulting from disposition alternatives are presented to provide decisionmakers with an understanding of the possible long-term implications of the policy of accepting foreign spent fuel in the U.S. The disposition alternatives are not a part of the policy, however.

All cases in this section which consider shipment of foreign spent fuel to the U.S. analyze the impacts and requirements resulting from geologic repository startup in the years 1985 and 1995. The Report to the President by the Interagency Review Group on Nuclear Waste Management (TID 29442) indicated that initial operation of the first geologic repository for high level waste (spent fuel or reprocessing waste) was expected between the years 1988 and 1992.

President Carter's Program on Radioactive Waste Management recently announced (February 12, 1980) the administration's position on nuclear waste management and estimated that a decision on the location of the first repository will be made around the year 1985, and initial operation of the first repository would begin in the mid-1990s. DOE's recent input to the NRC rulemaking on nuclear waste storage and disposal estimates that the first repository may be available between the years 1997-2006. To show the environmental effects of delayed repository opening beyond the year 1995, DOE expanded the analyses in the draft EIS (DOE/EIS-0040-D) to show the environmental effects associated with interim storage of foreign spent power reactor fuel in ISFS facilities with the first geologic repository startup in the year 2010. Startup of the geologic repository in the year 2010 was arbitrarily selected to establish an upper limit on startup of the geologic repository.

The scope of this volume is the environmental effects on the U.S. and global commons from implementation of the proposed U.S. Spent Fuel Storage Policy for foreign spent fuel and alternatives thereto. These cumulative effects in the U.S. and global commons were calculated by determining the total world environmental effects less those associated with regional effects resulting from operations in foreign nations. The world environmental effects are also set forth in this section for purposes of completeness. The regional environmental effects of operations in the territories of foreign states are not assessed in this volume. In this volume, the sum of the environmental effects on the U.S. and global commons are defined as being equal to the total world environmental effects less those associated with regional effects[1] that result from operations in foreign nations. The regional effects are defined as those on a hypothetical land area of nine million km^2 (an area equal to that of the United States) with the foreign nation carrying out the activities at the center of that area.

Environmental effects are evaluated in this analysis for interim storage and, in some of the cases, for reprocessing of the foreign spent fuel. Both options are discussed in Cases A, B, and C. In this analysis, the back-end operations of the fuel cycle are the important ones in the consideration of the Spent Fuel Policy. However, if the fuel is reprocessed and the recovered plutonium and uranium recycled, a decrease in virgin uranium feed requirements would result, and mining and milling activities for uranium would be reduced. Reduction in mining and milling activities would result in a significant decrease in radiation health effects to the population (primarily from a decrease in lung dose from radon gas) and in accidental mining and milling deaths. In fact, these reduced mining and milling effects more than offset the health effects and accidental deaths arising from the transportation, storage, reprocessing and ultimate disposition of the foreign spent fuel analyzed in this report.

In this volume, the reductions in health effects and accidental deaths as a result of decreased mining and milling activities are indicated in the tables showing the environmental effects of the cases considered. However, they are not included in the discussion of the effects for the various alternatives, because the mining and milling operations are not directly associated with the operations at the back-end of the fuel cycle discussed in this report.

B. Impact Analysis

The environmental impacts for each of the nine cases are presented in two parts: the effects on the nonproliferation objectives of the U.S. and other major environmental effects. This division is made for two reasons:

1) The effects on nonproliferation objectives cannot be presented in a quantitative manner. Estimates of the nonproliferation implications of the different alternatives considered in regard to the U.S. offer are necessarily judgmental.

2) Although the differences in major environmental effects among the cases differ roughly by a factor of ten, the effects in all cases are small.

C In the cases analyzed in this section, the radiation dose to the population and work force caused by operations with foreign spent fuel is less than 0.00001% of that received by the population from natural radiation sources during the same time period. The accidental deaths are less than 0.004% of the occupational accidental deaths that will occur in only the U.S. during the same time period. Because of the modest size of these environmental effects, nonproliferation effects are dominant.

B.1. Case A - Fuel Remains in Foreign Countries - No U.S. Support (Option 3 Fuel Schedule)

The U.S. Spent Fuel Storage Policy for foreign spent fuel is assumed not to be implemented in this case. Each foreign country is responsible for storage of its own spent fuel. Ultimately, the foreign countries are assumed to either 1) reprocess the spent fuel, recycle the plutonium and uranium and dispose of the reprocessing waste in foreign geologic repositories, or 2) dispose of the spent fuel in foreign geologic repositories. However, the foreign countries must make arrangements for interim storage of spent fuel until fuel reprocessing plants (FRP) and mixed oxide (MOX) fuel fabrication plants become available and/or geologic repositories become available for disposal of spent fuel.

The environmental effects of the actions in this case are determined, assuming the foreign nations construct fuel reprocessing plants with sufficient capacity to handle the LWR and CANDU spent fuel that become available. Foreign nations may support construction of multinational facilities or arrange for services by countries with facilities already available. These foreign nations are assumed to be the same nations identified in Section II D.3 for the Option 3 fuel schedule. Waste from reprocessing operations is assumed to be stored in foreign geologic repositories.

B.1.1 Effects on U.S. Nonproliferation Policy (Case A)

The U.S. policy is assumed not to be implemented in regard to foreign spent fuel in Case A. If the policy is not implemented, the U.S. would not accept spent fuel from other countries for storage. Any U.S. role in foreign spent fuel disposition would then depend only upon our broad political influence and the rights obtained under any new or modified agreements for cooperation in the peaceful uses of nuclear energy that may be negotiated, as well as applicable provisions of present agreements. Such action would amount to deferral or withdrawl of the President's offer of October 1977.

In the absence of a U.S. spent fuel storage offer, there will be some transportation of spent fuel among countries,either for storage or reprocessing of spent fuel. Transfers for reprocessing would also involve return shipments of waste and separated plutonium or mixed oxide fuel. It is believed that shipment of plutonium or unirradiated MOX fuel is easier to divert for use in construction of illicit nuclear devices than irradiated spent fuel and this case would, therefore, create the greatest proliferation risk of those considered. Accumulation of spent fuel at storage facilities also presents stocks of spent fuel that could be reprocessed to recover its contained plutonium.

The precise amount of shipments for interim storage or reprocessing will depend upon the fuel cycle policies and storage space available to nations. If the U.S. does not accept foreign spent fuel for storage, the proliferation risks would be greater than the risks associated with the U.S. acceptance of foreign spent fuel. It is believed that if the U.S. offer is made, foreign spent fuel storage would be minimized, and some foreign reprocessing would be forestalled. Thus, nuclear proliferation potential would be reduced. It is possible that other factors, including discussions in the International Nuclear Fuel Cycle Evaluation (INFCE), costs, physical security problems, national nonproliferation interests, or fuel cycle policies will induce nations currently interested in reprocessing to alternately choose to store their spent fuel. If this occurs and the U.S. has not made the offer for storage of foreign spent fuel, other nations may still be encouraged to build interim storage facilities or to negotiate bilateral, multinational, or international storage arrangements. However, such an outcome could also mean that spent fuel would remain in sensitive regions. In the absence of reprocessing, spent fuel itself is not a weapons-usable material; however, its continued presence does mean that a reprocessing option remains available.

If the U.S. decides not to accept foreign spent fuel for storage, then some of the nations lacking sufficient internal storage capability may turn to reprocessing as an alternative.

C If some nations develop internal facilities, then they will acquire sensitive facilities capable of producing material usable in nuclear explosive devices. Stocks of separated plutonium, which are directly usable in weapons or explosive devices, may be established. It is also possible that some nations may begin to produce mixed oxide fuels containing both plutonium and uranium. These MOX fuels can be put through a relatively simple chemical separation process to produce plutonium. The potential positive influence on the NPT or other safeguards undertakings would not be realized.

On balance, if the policy is not implemented, the U.S. would have less ability to promote its nonproliferation interests and
C to forestall the spread of reprocessing plants and the emergence of stocks of separated plutonium than if the policy is implemented.

B.1.2 Other Major Environmental Effects (Case A)

The major environmental effects of Case A (other than effects on U.S. nonproliferation policy), if the ultimate disposition of the foreign spent fuel is by reprocessing, are given in Tables III-3 through III-5. Table III-3 gives the impacts on the U.S. and global commons; and Table III-4 gives the impacts on the world, if an Option 3 fuel schedule is assumed. A breakdown of the effects due to the different activities associated with interim storage operations and with disposition activities is given in Tables III-3 and III-4.

The only environmental effect to the U.S. and global commons is a population dose commitment of about 5500 man-rem resulting in about 3 health effects because all operations involving the foreign spent fuel are carried out in foreign countries. The worldwide population dose commitment is about 7200 man-rem; and the occupational exposure is about 8700 man-rem, the combination
7-j resulting in about 10 health effects. Accidental deaths, resulting primarily from transportation accidents, will be about 8.

The environmental effects, if the foreign spent fuel is disposed of as waste in a geologic repository, were not determined explicitly. However, because of the reduced operations required if the fuel is not reprocessed, and by comparison with the results presented for Case D (foreign fuel shipped to U.S. and disposed of as waste in a U.S. geologic repository), it is clear that the environmental effects from spent fuel disposed of as waste are smaller than those presented in Tables III-3 through III-5 for the case when the spent fuel is reprocessed.

TABLE III-3

Major Environmental Effects to the U.S. and Global Commons in Case A[a]

	Population Whole Body Dose Commitment, man-rem			*Occupational Whole Body Exposure, man-rem*			*Health Effects from Population Dose Commitment and Occupational Exposure*[b]			*Accidental Deaths*		
Facility or Operation	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*
Transportation	-[c]	-	-	-	-	-	-	-	-	-	-	-
ISFS	-	-	-	-	-	-	-	-	-	-	-	-
FRP-MOX Plant	-	5480	5480	-	-	-	-	3.2	3.2	-	-	-
Geologic Repository	-	<1	<1	-	-	-	-	<0.0002	<0.0002	-	-	-
Total	-	5480	5480	-	-	-	-	3.2	3.2	-	-	-
Mining and Milling	-	-	-	-	-	-	-	-	-	-	-	-

a. Fuel Remains in foreign countries -- no U.S. support (Option 3 Fuel Schedule).

b. Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

TABLE III-4

Major Environmental Effects to the World in Case A[a]

Facility or Operation	Population Whole Body Dose Commitment, man-rem			Occupational Whole Body Exposure, man-rem			Health Effects from Population Dose Commitment and Occupational Exposure[b]			Accidental Deaths		
	Interim Operations	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*
Transportation	2.5	32	34	16	94	110	0.01	0.08	0.09	0.35	0.72	1.1
ISFS	-[c]	-	-	-	-	-	-	-	-	-	-	-
7-j FRP-MOX Plant	-	7140	7140	-	6300	6300	-	8.9	8.9	-	2.7	2.7
Geologic Repository	-	1	1	-	2240	2240	-	1.5	1.5	-	4.1	4.1
Total	2.5	7200	7200	16	8650	8700	0.01	10.5	10.5	0.35	7.5	7.9
Mining and Milling[d]	-	-3×10^{6} [e]	-3×10^{4} [e]	-	-3000[f]	-3000[f]	-120[g]	-120[g]	-	-	-31	-31

a. Fuel remains in foreign countries — no U.S. support (Option 3 Fuel Schedule).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

d. The incremental effects of the reduction in mining and milling requirements for uranium resulting from recycle of the plutonium and uranium from the foreign fuel are shown. The negative signs in the last line of data indicate a decrease in effects.

e. The population dose commitment from mining and milling activities results from inhalation of radon gas. It is expressed in units of man-rem to the lung, rather than man-rem to the whole body.

f. The occupational dose from mining and milling activities results from inhalation of radon gas and of particulates. It is expressed in units of working level months (WLM). A WLM is defined as exposure for 170 hours to air that contains any combination of short-lived radon daughters in one liter that will ultimately produce 1.3×10^{5} MeV of alpha energy or to an equivalent product of concentration and time.

g. 99.75% of the health effects arise from the mining and milling population dose.

TABLE III-5

Summary of Major Environmental Effects for Case A[a]

	Total	*Incremental Effects of Reduced Mining and Milling Requirements*[b] *(Not included in total)*
Population Whole Body Dose Commitment, man-rem		
U.S. and Global Commons	5500	0
World	7200	$-3\text{x}10^{6}$[c]
Occupational Whole Body Exposure, man-rem		
U.S. and Global Commons	0	0
World	8700	-3000[d]
Health Effects from Population Dose Commitment and Occupational Exposure[e]		
U.S. and Global Commons	3.2	0
World	10.5	-120[f]
Accidental Deaths		
U.S. and Global Commons	0	0
7-j World	7.9	-31

a. Fuel remains in foreign countries — no U.S. support (Option 3 Fuel Schedule).

b. The incremental effects of the reduction in mining and milling requirements for uranium resulting from recycle of the plutonium and uranium from the foreign fuel are shown. The negative signs indicate a decrease in effects.

c. The population dose commitment from mining and milling activities results from inhalation of radon gas. It is expressed in units of man-rem to the lung, rather than man-rem to the whole body.

d. The occupational dose from mining and milling activities results from inhalation of radon gas and of particulates. It is expressed in units of working level months (WLM). A WLM is defined as exposure for 170 hours to air that contains any combination of short-lived radon daughters in one liter that will ultimately produce 1.3×10^{5} MeV of alpha energy or to an equivalent product of concentration and time.

C *e.* Serious somatic and genetic 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 Volume 2 for more detail on methodology used in determining health effects.)

f. 99.75% of the health effects arise from the mining and milling population dose.

B.2. Case B - Fuel Remains in Foreign Countries - U.S. Supports Multinational Interim Storage (Option 3 Fuel Schedule)

In Case B, the U.S. Spent Fuel Storage Policy for foreign spent fuel is assumed to be implemented to the extent of the U.S. providing support for multinational storage outside the U.S. (Assistance could also be provided on a bilateral basis for foreign national storage facilities; this option is discussed as Case C.)

The multinational facility could be owned or operated under U.S. or international auspices. Formal arrangements could take the form of a multinational ISFS* facility under specific country or multiple country ownership and/or operation or under the auspices of an existing international organization, e.g., IAEA. Thus, interim storage of foreign spent fuel could be outside the country of origin. The sites for such facilities would be outside sensitive regions. United States assistance to such arrangements will be contingent on the degree to which these arrangements contributed to U.S. nonproliferation objectives. Depending upon the circumstances, the U.S. might be a direct participant or could limit its role to providing technical and or financial assistance.

The environmental effects of this case are based upon the following scenario. The U.S. and the foreign countries considered in Option 3 fuel schedule will reach mutual accord to construct a multinational ISFS facility with U.S. support in a country outside sensitive regions for storage of all or part of each country's spent fuel.

The spent fuel could ultimately be disposed of 1) by reprocessing the fuel, after interim storage in the multinational ISFS facility, followed by disposal of the reprocessing waste in a geologic repository or 2) by disposal of the spent fuel as waste in a geologic repository.

B.2.1 Effect on U.S. Nonproliferation Policy (Case B)

In Case B, the U.S. is assumed to support a multinational storage facility in a foreign country outside sensitive regions. The nonproliferation benefits from this case are greater than if bilateral U.S. support were provided for national facilities in eligible countries, because the countries eligible for bilateral support would have to be outside sensitive regions and show financial capability to support an expanded spent fuel storage program once U.S. assistance stops. (The bilateral support alternative is discussed in Section II C.3.)

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* ISFS - Independent Spent Fuel Storage (or storage facilities away from reactor).

Multinational foreign storage facilities could provide the following nonproliferation benefits. Nations without the necessary national storage facilities or nations seeking to demonstrate their respective intentions to observe nonproliferation obligations would have an alternative to reprocessing, retransferring for reprocessing, or maintaining spent fuel stocks inside sensitive regions. Multinational ownership and/or operation of spent fuel storage regimes could provide an additional barrier to diversion of material or reprocessing to obtain materials that could be used in nuclear weapons. International cooperation in spent fuel storage could enable additional countries to benefit from the availability of storage space and facilities. Any reduction in the number of spent fuel storage sites worldwide would facilitate the application of international safeguards and physical security.

U.S. assistance for such arrangements could provide an incentive for additional countries to accept more extensive nonproliferation assurances, e.g., to adhere to the NPT or to the Tlatelolco Treaty. The U.S. would approach the search for acceptable international fuel cycle arrangements with the added advantage of having made a positive contribution to the storage of foreign spent fuel. Other countries might then be motivated to make their own contribution. This approach will also be in keeping with the U.S. belief that each nation will have primary responsibility for resolving its own spent fuel storage problem.

Forecasting the precise quantities of spent fuel that may be accommodated under this alternative is difficult. The Option 3 fuel schedule was selected for this analysis. All of these countries may not take part in this offer, and the U.S. may exercise this option in combination with one or more other options. Selection of Option 3 fuel schedule maximizes the environmental effects of this case. To provide for storage sites outside sensitive regions, some countries from Option 2 and Option 3 will have to be involved. Furthermore, credible multinational or international arrangements would have to be relatively nondiscriminatory in offering membership in order to be acceptable from a diplomatic perspective.

However, the multinational policy would also present disadvantages that could prevent the realization of the benefits described above. In the absence of general international agreement on the requirements for multinational spent fuel storage, or of offers from other nations to accept foreign fuel on terms such as those proposed by the U.S., the lead time required for the establishment of such a policy and in turn the establishment of such facilities would likely be long. From the U.S. point of view, participation in a multinational program or in the storage program of another nation would provide fewer opportunities to control costs or to facilitate timely implementation.

B.2.2 Other Major Environmental Effects (Case B)

The major environmental effects, other than the effect on
nonproliferation discussed above, are not explicitly determined
for Case B because they are essentially the same to the effects
C presented for Case A, except that shipment from sensitive coun-
tries may require transportation of spent fuel by sea. This would
increase the population doses of Case A to U.S. and global com-
mons and the world by about 5 to 7 man-rem. Occupational expo-
sures would increase by 40 to 50 man-rem compared to the effects
of Case A. The impacts of Case A are discussed in Section III
B.1.2 and are shown in Tables III-3 through III-5.

If the foreign spent fuel is ultimately reprocessed following storage in a multinational ISFS, the reprocessing would probably occur at a later time than in Case A (U.S. policy not implemented). However, a delay in reprocessing will have little effect on the relative magnitude of the environmental effects. The impacts will be smaller if the spent fuel is disposed of in a geologic repository (as waste) as discussed in Section III B.1.2.

B.3 Case C - Fuel Remains in Foreign Countries - U.S. Supports National Interim Storage (Option 3 Fuel Schedule)

In Case C, the U.S. Spent Fuel Storage Policy for foreign
spent fuel is assumed to be implemented only to the extent of
providing support for national storage facilities abroad on a
bilateral basis. Eligible countries will be outside sensitive
regions and will be financially capable of supporting an expanded
storage program once initial U.S. assistance is terminated. In
each instance, cooperation would offer nonproliferation benefits
to U.S. policy. Decisions to offer U.S. assistance will be made
on a case-by-case basis. The assistance could take the form of
assistance in increasing the density of existing onsite reactor
storage pools through reracking and installation of neutron-
absorbing racks or assistance in the construction of ISFS facili-
13-v ties. In the case of sensitive regions, DOE may provide assistance
in expanding the capability of existing reactor storage pools
pending availability of storage capacity in U.S. or multinational
storage facilities (not located in sensitive regions). However,
DOE has no plans to provide financial support to national storage
in sensitive regions.

Because the offer of support for national storage arrangements will be made only to countries outside sensitive regions, the amount of foreign spent fuel that would be included in such an offer is actually equal to that covered by the Option 3 fuel schedule minus that covered by the Option 1 fuel schedule. However, the only major environmental effect that is influenced by this limit is the effect on the U.S. nonproliferation policy because, ultimately, it is assumed that the foreign countries either 1) reprocess the spent fuel with disposal of reprocessing waste in foreign geologic repositories and recycle the plutonium and uranium or 2) dispose of the spent fuel in foreign geologic repositories.

The environmental effects of this case are analyzed based upon the following scenario. Each foreign country considered in the Option 3 fuel schedule except those in sensitive regions agrees to cooperate with the U.S. and with U.S. aid develop an ISFS facility for interim spent fuel storage within its own national boundary. Part or all of its spent fuel would be stored in this facility. Again, the spent fuel could ultimately be disposed of by reprocessing the fuel, after interim storage in the ISFS facility, followed by disposal of the reprocessing waste in a geologic repository or by disposal of the spent fuel as waste in a geologic repository.

B.3.1 Effect on U.S. Nonproliferation Policy (Case C)

The beneficial nonproliferation impacts of Case C are less than those described for Case B in Section III B.2 where U.S. support of multinational storage arrangements are considered. The bilateral offers considered in Case C would be restricted to countries outside sensitive regions that will be financially capable of supporting an expanded storage program once U.S. assistance is terminated. However, any increases in foreign spent fuel storage capability would provide alternatives to reprocessing or retransfers for reprocessing to more countries. From the U.S. perspective, such opportunities could lead to removal of diplomatic irritants in relations with the countries in question. Such assistance could provide an incentive for additional countries to accept more extensive nonproliferation assurances, e.g. to adhere to the NPT or to the Tlatelolco Treaty. The U.S. would approach the search for acceptable international fuel cycle arrangements with the added advantage of having made a positive contribution. Other countries might then be motivated to make their own contributions.

The U.S. could give preference to countries that do not undertake or that suspend new conventional reprocessing activities or that avoid entering into major new commercial reprocessing contracts with third countries. This approach would also be in keeping with the U.S. belief that each nation has the primary responsibility for resolving its own spent fuel problems. Assistance could be conditional on a nation demonstrating good faith efforts to construct storage facilities and on having a need for U.S. assistance in building or expanding facilities. "Need" would include cases in which reprocessing is a likely alternative to expanding local storage facilities, or in which U.S. assistance might lead to NPT adherence or similar actions producing a nonproliferation benefit from the standpoint of U.S. policy.

On the other hand, this alternative does present disadvantages. Some countries may not have readily available storage sites which meet environmental and regulatory requirements. Depending upon the level of U.S. assistance, some countries, particularly those with smaller nuclear power programs, could still have difficulties in amortizing the costs of investing in storage facilities, as compared to costs of shipping spent fuel to foreign storage sites or foreign reprocessing plants. Furthermore, this alternative would not meet the needs of countries within sensitive regions in which removal of spent fuel from local storage will contribute to increased confidence that nonproliferation obligations will be observed and to reduction of fears about the possible misuse of the nuclear power programs in the nations concerned.

In addition, U.S. assistance to national storage could be more costly and time-consuming than accepting foreign spent fuel for storage in the U.S. A national storage program involving more diverse national situations would be harder to implement, and the U.S. might be able to assist fewer countries. A more limited program would, in turn, increase the risk that U.S. policy toward spent fuel disposition could be interpreted abroad as discriminatory by ineligible nations (i.e., those located within sensitive regions).

As in other cases presented in this analysis, it is difficult to forecast the quantities of spent fuel that would be involved in implementation, particularly since the situations of individual nations are so diverse.

B.3.2 Other Major Environmental Effects (Case C)

The major environmental effects, other than the effects on nonproliferation discussed above, were not explicitly determined for Case C because they were essentially identical to the
C effects presented for Case A, except that shipments from sensitive countries might require transportation of spent fuel by sea. Shipments by sea probably would involve shorter transport distances for Case C than for Case B. Transportation of spent fuel by sea in Case C would increase the population doses to the U.S. and global commons and the world by about three to five man-rem. Occupational doses would increase, in Case C, about 20 to 30 man-rem compared to the effects of Case A. The impacts of Case A are discussed in Section III B.1.2 and are shown in Tables III-3 through III-5. The impacts would be smaller if the spent fuel were disposed of in a geologic repository, as discussed in Section III B.1.

B.4 Case D - Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 3 Fuel Schedule)

The U.S. offer to accept foreign spent fuel for storage is assumed to be fully implemented in Case D. All the nations considered under the Option 3 fuel schedule agree to ship part or all of their spent fuel to the U.S. for interim storage. The U.S. Government provides ISFS facilities and a geologic repository for storage of both foreign and domestic spent fuel. The geologic repository becomes available in the year 1985 and at that time, some
6-b of the spent fuel will be stored in the repository. (It is recognized that startup of the geologic repository will not be achieved as early as the year 1985.) This case is also analyzed, assuming the startup of the geologic repository is delayed ten years to the year 1995.

The environmental effects of activities associated with the foreign spent fuel in Case D are analyzed, assuming a decision is made in the year 1990 not to reprocess the foreign spent fuel or domestic spent fuel. The spent fuel is then disposed of in the U.S. geologic repository.

The U.S. Spent Fuel Storage Policy is assumed to be fully implemented for U.S. spent fuel in Case D to enable the incremental effects of the operations associated with the foreign fuel to be determined. However, if the policy were not implemented for domestic fuel, the effects of the operations required for storing the foreign fuel in U.S. facilities and disposing of the foreign fuel in a U.S. geologic repository will remain virtually the same.

C In Case D, the Option 3 fuel schedule is assumed, and it includes fuel shipments from:

- Countries in sensitive regions
- A limited number of other countries with spent fuel storage problems
- E A small number of larger, industrialized non-nuclear weapons countries.

In each instance, the action taken will be determined on a case-by-case basis and would be based upon the benefits to the U.S. nonproliferation interests and the apparent need for spent fuel shipment.

C All of the countries identified by the Option 3 fuel schedule are assumed to make agreements with the U.S. to ship all or part of their spent fuel in the U.S. for storage. In the year 1990, a decision is assumed to be made to dispose of the spent fuel; and the foreign spent fuel is disposed of, along with U.S. spent fuel, in a U.S. geologic repository.

In Cases G and H, foreign spent fuel is also assumed to be shipped to the U.S. and is later disposed of in a U.S. geologic repository. However, the Option 2 fuel schedule is considered in Case G and the Option 1 fuel schedule, in Case H.

B.4.1 Effects on Nonproliferation Policy (Case D)

The nonproliferation impacts for all three foreign fuel shipment schedules are discussed in detail in Section II D.3. The nonproliferation effects of foreign spent fuel shipments with the Option 3 fuel schedule, considered in Case D, are potentially the most comprehensive and beneficial of the three options.

The comprehensive nature of the offer under the Option 3 fuel schedule will make it appear less discriminatory and, therefore, more attractive to all potentially eligible and cooperating countries. Decisions by some of the larger industrialized countries to take advantages of the offer and to defer reprocessing may have beneficial precedential impacts on the international community's approach to the nuclear fuel cycle. These nations also have the financial and technical resources to support the study and possible creation of national or multinational spent fuel storage facilities. Adherence to the nonproliferation treaty could be encouraged. In general, this option would contribute to improved international cooperation and a sense of common purpose in the nuclear area and would increase the effectiveness of U.S. nonproliferation efforts.

B.4.2 Other Major Environmental Effects (Case D)

The major environmental effects of Case D (other than effects on U.S. nonproliferation policy) are given in Tables III-6 through III-8, assuming startup of the U.S. geologic repository in the years 1985 or 1995. Table III-6 gives the effects on the U.S. and global commons, and Table III-7 gives the effects on the world. A breakdown of the effects due to various activities associated with interim storage activities and with disposition activities is presented.

Table III-8 summarizes the effects on the U.S. and global commons and on the world. All operations involving the foreign spent fuel are carried out in the U.S., except for maritime transportation and cask loading onto ships in the foreign countries. Thus, the effects on the U.S. and global commons and on the world are the same except for those associated with loading spent fuel casks of the foreign spent fuel onto the ship, and this makes a slight contribution to the total (10% or less).

TABLE III-6

Major Environmental Effects to the U.S. and Global Commons in Case D[a]

	Facility or Operation	*Population Whole Body Dose Commitment, man-rem*			*Occupational Whole Body Exposure, man-rem*			*Health Effects from Population Dose Commitment and Occupational Exposure*[b]			*Accidental Deaths*		
		Interim Operations	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*
	1985 Startup of U.S. Geologic Repository												
	Transportation	36	-[c]	36	240	-	240	0.19	-	0.19	1.2	-	1.2
7-j	ISFS	690	-	690	200	-	200	0.55	-	0.55	0.4	-	0.4
	FRP-MOX Plant	-	-	-	-	-	-	-	-	-	-	-	-
7-j	Geologic Repository	-	120	120	-	260	260	-	0.28	0.28	-	1.8	1.8
	Total	730	120	850	440	260	700	0.74	0.28	1.02	1.6	1.8	3.4
	1995 Startup of Geologic Repository												
	Transportation	40	-	40	220	-	220	0.17	-	0.17	1.3	-	1.3
7-j	ISFS	2800	-	2800	1000	-	1000	2.37	-	2.37	1.1	-	1.1
	FRP-MOX Plant	-	-	-	-	-	-	-	-	-	-	-	-
7-j	Geologic Repository	-	110	110	-	260	260	-	0.27	0.27	-	1.8	1.8
	Total	2840	110	2950	1220	260	1480	2.54	0.27	2.81	2.4	1.8	4.2

a. Fuel shipped to U.S. for storage — later disposed of in U.S. geologic repository (Option 3 Fuel Schedule).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

TABLE III-7

Major Environmental Effects to the World in Case D[a]

	Facility or Operation	Population Whole Body Dose Commitment, man-rem			Occupational Whole Body Exposure, man-rem			Health Effects from Population Dose Commitment and Occupational Exposure[b]			Accidental Deaths		
		Interim Operations	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*
	1985 Startup of Geologic Repository												
	Transportation	36	-[c]	36	310	-	310	0.21	-	0.21	1.2	-	1.2
7-j	ISFS	690	-	690	200	-	200	0.57	-	0.57	0.4	-	0.4
	FRP-MOX Plant	-	-	-	-	-	-	-	-	-	-	-	-
7-j	Geologic Repository	-	120	120	-	260	260	-	0.28	0.28	-	1.8	1.8
	Total	730	120	850	510	260	770	0.78	0.28	1.06	1.6	1.8	3.4
	1995 Startup of Geologic Repository												
	Transportation	40	-	40	270	-	270	0.18	-	0.18	1.3	-	1.3
7-j	ISFS	2800	-	2800	1000	-	1000	2.39	-	2.39	1.1	-	1.1
	FRP-MOX Plant	-	-	-	-	-	-	-	-	-	-	-	-
7-j	Geologic Repository	-	110	110	-	260	260	-	0.27	0.27	-	1.8	1.8
	Total	2840	110	2950	1270	260	1530	2.57	0.27	2.84	2.4	1.8	4.2

a. Fuel shipped to U.S. for storage — later disposed of in U.S. geologic repository (Option 3 Fuel Schedule).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

TABLE III-8

Summary of Major Environmental Effects for Case D[a]

	Startup Date of Geologic Repository	
	1985	*1995*
Population Whole Body Dose Commitment, man-rem		
U.S. and Global Commons	850	2950
World	850	2950
Occupational Whole Body Exposure, man-rem		
C U.S. and Global Commons	700	1480
World	770	1530
Health Effects from Population Dose Commitment and Occupational Exposure[b]		
U.S. and Global Commons	1.02	2.81
World	1.06	2.84
Accidental Deaths		
7-j U.S. and Global Commons	3.4	4.2
World	3.4	4.2

a. Fuel shipped to the U.S. for storage and later disposed of in the U.S. geologic repository (Option 3 Fuel Schedule).

C *b.* Serious somatic and genetic health effects calculated from radiation dose, 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 Volume 2 for more detail on metholology used in determining health effects.)

The whole body dose commitment to the populations is 850 man-rem if the U.S. geologic repository becomes available in the year 1985 and 2950 man-rem if the repository becomes available in the year 1995. The increase arises because of the interim storage of a larger amount of spent fuel for a longer time. In a similar manner, the occupational exposure increases from about 700 man-rem for repository startup in the year 1985 to about 1500 man-rem for repository startup in the year 1995. The combined population and occupational exposures are expected to result in about one health effect for the 1985 geologic repository startup and about three
7-j health effects for the 1995 geologic repository startup. About three or four accidental deaths are expected for startup in the year 1985 or 1995.

B.5 Case E - Fuel Shipped to U.S. - Later Returned for Reprocessing (Option 3 Fuel Schedule)

In Case E, foreign spent fuel is assumed to be shipped to the U.S. for storage from each of the countries identified in the Option 3 fuel schedule and later returned for foreign reprocessing, fuel fabrication, and recycling under conditions that meet the nonproliferation objectives of the U.S. This case could also be applied to the Option 2 fuel schedule. Although contrary to the present U.S. policy, this case is included for completeness under the NEPA process.

The location of the foreign spent fuel reprocessing and recovery of plutonium and uranium that is subsequently fabricated into fuel assemblies could be in a multinational facility under specific country or multiple country ownership and/or operation, and under the auspices of an existing international organization, e.g., IAEA. Fabricated MOX fuel containing plutonium would not be returned to countries in sensitive areas. The return of foreign spent fuel will be contingent upon acceptable nonproliferation safeguards to restrict the locations of sensitive facilities and activities, and to control the location of sensitive materials.

The environmental effects of Case E were analyzed, assuming that each country identified in the Option 3 fuel schedule ships spent fuel to the U.S. for storage. A decision that the U.S. will reprocess and recycle U.S. spent fuel and return the foreign spent fuel in lieu of repayment for any residual value of the contained plutonium and uranium is assumed to be made in the year 1990.

B.5.1 Effects on U.S. Nonproliferation Policy (Case E)

The nonproliferation effects of shipment of foreign spent fuel to the U.S. for storage are discussed in detail in Sections II D.3 and III B.4.1. However, in Case E and in Cases F-1 and F-2, reprocessing of the foreign spent fuel and recycling of the recovered plutonium and uranium is considered. Therefore, further nonproliferation considerations arise.

Under Case E, the U.S. is assumed to decide in the year 1990 to reprocess its domestic spent fuel by using a proliferation-resistant technology. The October 1977 spent fuel storage offer provides that in such an event the U.S. would either return spent fuel to the original shipper with an appropriate storage charge refund to be determined at the time or provide compensation for any net fuel value. In Case E, the foreign fuel is assumed to be returned for reprocessing. In Case F-1, the possibility of reprocessing the foreign fuel in the U.S. and recycling the recovered plutonium and uranium by U.S. power reactors is considered.

Case F-2 considers the possibility of reprocessing foreign fuel in the U.S. and returning plutonium and uranium to foreign countries for recycle in their power reactors.

In Case E, nonproliferation considerations would be evaluated on a case-by-case basis to determine whether a given shipper would be offered compensation or a return of his spent fuel. Spent fuel will not be returned to countries within sensitive regions where its presence could contribute to an enhanced risk of proliferation or to an increase in international tensions. The U.S. would also not favor returning spent fuel for reprocessing in countries that did not previously possess reprocessing plants or mixed oxide fuel (MOX) fabrication facilities. Such countries could arrange for existing reprocessing and fabrication services in other countries or multinational facilities. U.S. policy will continue to support restricting such sensitive activities as reprocessing to as few locations as possible. Appropriate institutional arrangements, international safeguards, and proliferation-resistant technologies would apply to such reprocessing plants as did operate. Any policy of returning spent fuel for reprocessing under conditions that take account of nonproliferation considerations would also be predicated on the development and use of technologies and institutional arrangements that minimized the risk of diversion of refabricated fuel produced in secure facilities.

Actual demand for returns of spent fuel would depend upon several factors, for example, the availability of reprocessing services in the U.S. and abroad. Consequently, it may be more attractive economically for countries considering spent fuel returns to contract for reprocessing in the U.S. if such services are available. The availability of reprocessing services in the U.S. will depend upon the lead time available before the prospective 1990 decision to build and license facilities. Case F-1, discussed in Section III B.6, considers the impacts of reprocessing the foreign fuel in the U.S. and recycling the separated plutonium and uranium in U.S. power reactors. The impacts of reprocessing in the U.S. of foreign spent fuel and of returning the separated plutonium and uranium to foreign countries for recycle are considered in Case F-2, discussed in Section III B.7.

If the U.S. decides in the year 1990 to reprocess, then approximately six to ten years may be required until the first facility using appropriate technology can start up in this country. The willingness to wait for U.S. facilities to open by countries eligible for spent fuel returns would be a function of their need and desire to use fuels other than slightly enriched uranium fuels in present generation light water reactors and of their need to begin to stockpile fuels for use in breeder reactors. Given present international uncertainties concerning the timing of breeder introduction and the adequacy of world uranium supplies to support projected demand for nuclear power, it is not possible at this time to forecast world requirements for mixed oxide fuel stockpiles.

The availability of foreign reprocessing services will also be a factor in actual demand for spent fuel returns from U.S. storage. Most probably many of the smaller countries eligible for the U.S. spent fuel storage offer will not construct national reprocessing facilities for economic reasons. If U.S. reprocessing services are not available at the time spent fuel returns are offered, then these countries may elect one of the following courses:

1) Contract for reprocessing services in another country

2) Continue to store their spent fuel in the U.S. until U.S. services are available

3) Accept a cash payment or equivalent value in low enriched fuel for any net value in lieu of any return.

U.S. policy will oppose the construction and operation of national reprocessing plants in countries not already possessing such facilities. If reprocessing services in another country are used, then the U.S. would screen each such retransfer request for its nonproliferation implications.

The foregoing prospects for return of spent fuel to countries that have made such shipments to the U.S. for storage have nonproliferation implications. A selective policy of approving spent fuel returns from the U.S. could be used to discourage the spread of sensitive facilities on a national basis. Approvals for retransfers for reprocessing could be restricted to a few facilities with appropriate international safeguards, institutional arrangements, and technological barriers to proliferation. Alternatively, the U.S. could withhold approval of any or some returns until a few multinational fuel cycle centers with similar controls and technology could be established. However, unless the planning and development of such facilities were already underway at the time of the U.S. decision to reprocess, the lead time for the establishment of multinational fuel cycle centers could be quite long. As noted in Case F-2, reprocessing of foreign spent fuel in the U.S. followed by return of the separated plutonium and uranium for the foreign countries in form of proliferation-resistant refabricated fuel may offer limited nonproliferation advantages.

Retransfers of foreign spent fuel from the U.S. after the U.S. reaches a decision to reprocess spent fuel (Case E) could present proliferation risks. A selective policy on retransfers could discourage countries intent on building national reprocessing facilities from accepting the U.S. spent fuel storage offer since their spent fuel might not be returned. A U.S. decision to proceed with domestic reprocessing while denying other countries the opportunity to reprocess their own spent fuel would be interpreted as discriminatory. Other countries might conclude that they were being placed at a competitive or technological disadvantage. However, the U.S. could avoid this disadvantage by linking its plans for reprocessing to the establishment of multinational fuel cycle centers open to countries meeting appropriate nonproliferation obligations. Such linkage would assume that U.S. and world needs for breeder fuels and/or mixed oxide fuels for recycle into light water reactors could be delayed until the establishment of such centers.

If a U.S. decision is made to allow spent fuel returns, proliferation-resistant technology is assumed to be available; however, the real security and benefits of such technology remain unproved. Reprocessing and recycling in any form still represent more of a proliferation risk than interim storage and disposal of spent fuel. Returns of spent fuel cooled for a long period of time will place into international commerce material that can be reprocessed for its plutonium content more easily than recently discharged spent fuel. Proliferation-resistant fuel cycle techno-
C | logy will not improve the security of this long-cooled material.

B.5.2 Other Major Environmental Effects (Case E)

The major environmental effects of Case E (other than effects on U.S. nonproliferation policy) are given in Tables III-9 through III-11.

Table III-11 summarizes the effects on the U.S. and global commons and on the world. The population whole body dose commitment to the U.S. and global commons is about 6900 man-rem, and the occupation exposure is about 440 man-rem, resulting in about four health effects. The population whole body dose commitment to the world is about 8300 man-rem; and the occupational exposure is about 7900 man-rem, resulting in 11 health effects. The number of
7-j | accidental deaths expected in the U.S. and global commons is about two; in the world, about eight.

B.6 Case F-1 - Fuel Shipped to U.S. - Later Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule)

In Case F-1, the foreign countries identified as participating in the Option 3 fuel schedule are assumed to each agree to ship all or part of their spent fuel to the U.S. for storage. This case could also be applied to Option 1 and 2 fuel schedules. The U.S. Government provides ISFS facilities and a geologic

TABLE III-9

Major Environmental Effects to the U.S. and Global Commons in Case E[a]

Facility or Operation	*Population Whole Body Dose Commitment, man-rem*			*Occupational Whole Body Exposure, man-rem*			*Health Effects from Population Dose Commitment and Occupational Exposure*[b]			*Accidental Deaths*		
	Interim Operations	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*
Transportation	15	-[c]	15	85	-	85	0.07	-	0.07	0.49	-	0.49
7-j ISFS	960	-	960	260	-	260	0.76	-	0.76	0.38	-	0.38
FRP-MOX Plant	-	5930	5930	-	-	-	-	3.4	3.4	-	-	-
Geologic Repository	-	28	28	-	94	95	-	0.09	0.09	-	0.71	0.71
Total	980	5960	6930	345	94	440	0.83	3.5	4.3	0.87	0.71	1.6
Mining and Milling	-	-	-	-	-	-	-	-	-	-	-	-

a. Fuel shipped to U.S. – later returned for reprocessing (Option 3 Fuel Schedule, 1985 startup of U.S. geologic repository).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

TABLE III-10

Major Environmental Effects to the World in Case E[a]

Facility or Operation	*Population Whole Body Dose Commitment, man-rem*			*Occupational Whole Body Exposure, man-rem*			*Health Effects from Population Dose Commitment Occupational Exposure*[b]			*Accidental Deaths*		
	Interim Operations	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*
Transportation	18	16	34	113	49	162	0.09	0.04	0.132	0.84	0.72	1.6
7-j ISFS	960	-[c]	960	260	-	260	0.76	-	-	0.38	-	0.38
FRP-MOX Plant	-	7240	7240	-	6240	6240	-	8.9	8.9	-	2.7	2.7
Geologic Repository	-	28	28	-	1250	1250	-	0.9	1.6	-	3.7	3.7
Total	980	7280	8260	370	7540	7910	0.85	9.8	10.6	1.2	7.1	8.3
Mining and Milling[d]	-	-3×10^{-6}[e]	-3×10^{-6}[e]	-	-3000[f]	-3000[f]	-	-120[g]	-120[g]	-	-31	-31

a. Fuel shipped to the U.S. and later returned for reprocessing (Option 3 Fuel Schedule, 1985 startup of U.S. geologic repository).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

d. The incremental effects of the reduction in mining and milling requirements for uranium resulting from recycle of the plutonium and uranium from the foreign fuel are shown. The negative signs in the last line of data indicate a decrease in effects.

e. The population dose commitment from mining and milling activities results from inhalation of radon gas. It is expressed in units of man-rem to the lung, rather than man-rem to the whole body.

f. The occupational dose from mining and milling activities results from inhalation of radon gas and of particulates. It is expressed in units of working level months (WLM). A WLM is defined as exposure for 170 hours to air that contains any combination of short-lived radon daughters in one liter that will ultimately produce 1.3×10^5 MeV of alpha energy or to an equivalent product of concentration and time.

g. 99.75% of the health effects arise from the mining and milling population dose.

TABLE III-11

Summary of Major Environmental Effects for Case E[a]

	Total	*Incremental Effect of Reduced Mining and Milling Requirements*[b] *(Not included in total)*
Population Whole Body Dose Commitment, man-rem		
U.S. and Global Commons	6930	0
World	8260	-3×10^{6}[c]
Occupational Whole Body Exposure, man-rem		
U.S. and Global Commons	440	0
World	7910	-3000[d]
Health Effects from Population Dose Commitment and Occupational Exposure[e]		
U.S. and Global Commons	4.3	0
World	10.6	-120[f]
Accidental Deaths		
7-j U.S. and Global Commons	1.6	0
World	8.3	-31

a. Fuel shipped to U.S. and later returned for reprocessing (Option 3 Fuel Schedule, 1985 startup of U.S. geologic repository).

b. The incremental effects of the reduction in mining and milling requirements for uranium resulting from recycle of the plutonium and uranium from the foreign fuel are shown. The negative signs indicate a decrease in effects.

c. The population dose commitment from mining and milling activities results from inhalation of radon gas. It is expressed in units of man-rem to the lung, rather than man-rem to the whole body.

d. The occupational dose from mining and milling activities results from inhalation of radon gas and of particulates. It is expressed in units of working level months (WLM). A WLM is defined as exposure for 170 hours to air that contains any combination of short-lived radon daughters in one liter that will ultimately produce 1.3×10^5 MeV of alpha energy or to an equivalent product of concentration and time.

C *e.* Serious somatic and genetic 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 Volume 2 for more detail on methodology used in determining health effects.)

f. 99.75% of the health effects arise from the mining and milling population dose.

repository for storage of U.S. and foreign spent fuel. The geologic repository will become available in the year 1985, at which time limited amounts of spent fuel will be stored in the repository.
6-b (It is recognized that startup of the geologic repository probably will not be achieved as early as the year 1985.)

A decision is assumed to be made in the year 1990 that the U.S. will reprocess both the U.S. and foreign fuel and recycle the plutonium and uranium from both the U.S. and foreign spent fuel in U.S. power reactors. A decision to reprocess spent fuel would require that reprocessing facilities, containing adequate safeguards to meet the nonproliferation objectives of the U.S., would be constructed. The reprocessing waste would be disposed of in a geologic repository. Although contrary to present U.S. policy, this is included for completeness under the NEPA process.

In all cases involving acceptance of foreign fuel for storage, the U.S. will assume full, irrevocable title to the foreign spent fuel. In Case F-1, the U.S. reprocesses the foreign fuel and recycles the recovered plutonium and uranium in U.S. power reactors. Any residual value of the foreign fuel will be the subject of negotiations between the U.S. and foreign countries.

Case F-1 is analyzed, assuming that reprocessing in the U.S. of the foreign and U.S. fuel will begin in the year 1998, and will be completed in the year 2028. (The foreign spent fuel constitutes about 16% of the total foreign plus domestic fuel reprocessed.) The reprocessing waste will be disposed of in a U.S. geologic repository.

B.6.1 Effect on U.S. Nonproliferation Policy (Case F-1)

In Case F-1, the U.S. is assumed to decide in the year 1990 to reprocess its domestic spent fuel and foreign spent fuel that has been placed in storage. A proliferation-resistant technology is used. All recovered material is recycled within the U.S. The October 1977 spent fuel storage offer provides that, in such an event, the U.S. will provide compensation to the original shipping countries for any net fuel value on the same basis as compensation (if any) is provided to domestic utilities. Required reprocessing facilities are assumed to be in place or to become available in a more gradual implementation of this program. Reprocessing waste from foreign and domestic fuel is disposed of in a U.S. geologic facility.

This alternative would offer some nonproliferation benefits. Some international commerce in mixed-oxide fuels would be avoided. All countries shipping spent fuel to the U.S. can be treated equally with respect to compensation for any net fuel value in spent fuel. Reprocessing and recycling in the U.S. would contribute to forestalling the spread of sensitive facilities abroad.

Some of the reprocessing, within the U.S., could be accomplished in a multinational fuel cycle center that could offer investment and ownership opportunities to other nations.

However, this alternative also presents some significant problems. Other nations may not be willing to forego access to mixed oxide fuels that may be needed for breeder reactor startup, especially if the U.S. begins to use such fuels. Some nations may feel that restricting reprocessing to the U.S. is discriminatory, although establishment of a multinational fuel cycle center could provide for a form of participation. Even if a multinational fuel cycle center is established, some nations could decide to stop sending spent fuel to the U.S. for storage, choosing instead to arrange for reprocessing or other arrangements affording them access to a supply of mixed oxide fuels. Furthermore, establishment of a multinational fuel cycle center in the U.S. will require resolution of presently unresolved questions concerning economic feasibility, cost, institutional and legal arrangements, including status of the organization within the U.S., management, and access to technology. In the absence of a general international agreement on reprocessing, a U.S. attempt to monopolize such services could lead to the spread of sensitive facilities or to less control over international commerce in mixed oxide fuels.

If a U.S. decision is made to reprocess, proliferation-resistant technology is assumed to be available. However, the real security and benefits of such technology remain unproved. Other nations could choose to adopt the same technology used in the U.S. but with fewer associated institutional controls.

B.6.2 Other Major Environmental Effects (Case F-1)

The major environmental effects of Case F-1 (other than effects on U.S. nonproliferation policy) are given in Tables III-12 through III-14. Table III-12 gives the effects on the U.S. and global commons, and Table III-13 gives the effects on the world. A breakdown of the effects from the various operations associated with interim storage and with disposition facilities is given in Tables III-12 and III-13 and summarized in Table III-14.

Except for maritime transportation and cask loading onto ships in the foreign countries, all operations involving the foreign spent fuel are carried out in the U.S. Thus, the effects on the U.S. and global commons and on the world are the same except for those associated with loading casks containing foreign spent fuel onto the ship, and this makes a very slight contribution to the total (about 1% or less).

TABLE III-12

Major Environmental Effects to the U.S. and Global Commons in Case F-1[a]

Facility or Operation	*Population Whole Body Dose Commitment, man-rem* Interim Operations	Dispositon Activities	Total	*Occupational Whole Body Exposure, man-rem* Interim Operations	Disposition Activities	Total	*Health Effects from Population Dose Commitment Occupational Exposure*[b] Interim Operations	Disposition Activities	Total	*Accidental Deaths* Interim Operations	Disposition Activities	Total
Transportation	37	9.1	46	250	27	280	0.19	0.03	0.22	1.4	0.72	2.1
7-j ISFS	960	-[c]	965	260	-	260	0.77	-	0.77	0.4	-	0.4
FRP-MOX Plant	-	10,290	10,290	-	4580	4580	-	9.5	9.5	-	2.3	2.3
Geologic Repository	-	190	190	-	690	690	-	0.6	0.6	-	4.6	4.6
Total	1000	10,500	11,500	510	5300	5810	0.96	10.1	11.1	1.8	7.6	9.4
Mining and Milling[d]	0	-3×10^{6}[e]	-3×10^{6}[e]	0	-3000[f]	-3000[f]	0	-120[g]	-120[g]	0	-31	-31

a. Fuel shipped to the U.S. and later reprocessed and recycled in the U.S. (Option 3 Fuel Schedule).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

d. The incremental effects of the reduction in mining and milling requirements for uranium resulting from recycle of the plutonium and uranium from the foreign fuel are shown. The negative signs in this line of data indicate a decrease in effects.

e. The population dose commitment from mining and milling activities results from inhalation of radon gas. It is expressed in units of man-rem to the lung, rather than man-rem to the whole body.

f. The occupational dose from mining and milling activities results from inhalation radon gas and of particulates. It is expressed in units of working level months (WLM). A WLM is defined as exposure for 170 hours to air that contains any combination of short-lived radon daughters in one liter that will ultimately produce 1.3×10^5 MeV of alpha energy or to an equivalent product of concentration and time.

g. 99.75% of the health effects arise from the mining and milling population dose.

TABLE III-13

Major Environmental Effects to the World in Case F-1[a]

Facility or Operation	*Population Whole Body Dose Commitment, man-rem* Interim Operations	Disposition Activities	Total	*Occupational Whole Body Exposure, man-rem* Interim Operations	Disposition Activities	Total	*Health Effects from Population Dose Commitment and Occupational Exposure*[b] Interim Operations	Disposition Activities	Total	*Accidental Deaths* Interim Operations	Disposition Activities	Total
Transportation	37	9.1	46	310	27	340	0.23	0.03	0.26	1.4	0.72	2.1
7-j ISFS	960	-[c]	960	260	-	260	0.77	-	0.77	0.4	-	0.4
FRP-MOX Plant	-	10,290	10,290	-	4580	4580	-	9.5	9.5	-	2.3	2.3
Geologic Repository	-	190	190	-	690	690	-	0.62	0.6	-	4.6	4.6
Total	1000	10,500	11,500	570	5300	5870	1.0	10.1	11.1	1.8	7.6	9.4
Mining and Milling[d]	0	-3×10^6[e]	-3×10^6[e]	0	-3000[f]	-3000[f]	0	-120[g]	-120[g]	0	-31	-31

a. Fuel shipped to the U.S. and later reprocessed and recycled in the U.S. (Option 3 Fuel Schedule).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

d. The incremental effects of the reduction in mining and milling requirements for uranium resulting from recycle of the plutonium and uranium from the foreign fuel are shown. The negative signs indicate a decrease in effects.

e. The population dose commitment from mining and milling activities results from inhalation of radon gas. It is expressed in units of man-rem to the lung, rather than man-rem to the whole body.

f. The occupational dose from mining and milling activities results from inhalation of radon gas and of particulates. It is expressed in units of working level months (WLM). A WLM is defined as exposure for 170 hours to air that contains any combination of short-lived radon daughters in one liter that will ultimately produce 1.3×10^5 MeV of alpha energy or to an equivalent product of concentration and time.

g. 99.75% of the health effects arise from the mining and milling population dose.

TABLE III-14

Summary of Major Environmental Effects for Case F-1[a]

	Total	*Incremental Effect of Reduced Mining and Milling Requirements*[b] *(Not Included in Total Column)*
Population Whole Body Dose Commitment, man-rem		
U.S. and Global Commons	11,500	-3×10^{6}[c]
World	11,500	-3×10^{6}[c]
Occupational Whole Body Exposure, man-rem		
U.S. and Global Commons	5810	-3000[d]
World	5870	-3000[d]
Health Effects from Population Dose Commitment and Occupational Exposure[e]		
U.S. and Global Commons	11.1	-120[f]
World	11.1	-120[f]
Accidental Deaths		
7-j U.S. and Global Commons	9.4	-31
World	9.4	-31

a. Fuel shipped to U.S. and later reprocessed and recycled in the U.S. Option 3 Fuel Schedule.

b. The incremental effects of the reduction in mining and milling requirements for uranium resulting from recycle of the plutonium and uranium from the foreign fuel are shown. The negative signs indicate a decrease in effects.

c. The population dose commitment from mining and milling activities results from inhalation of radon gas. It is expressed in units of man-rem to the lung, rather than man-rem to the whole body.

d. The occupational dose from mining and milling activities results from inhalation of radon gas and of particulates. It is expressed in units of working level months (WLM). A WLM is defined as exposure for 170 hours to air that contains any combination of short-lived radon daughters in one liter that will ultimately produce 1.3×10^{5} MeV of alpha energy or to an equivalent product of concentration and time.

C *e.* Serious somatic and genetic 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 Volume 2 for more detail on methodology used in determining health effects.)

f. 99.75% of the health effects arise from the mining and milling population dose.

The population whole body dose commitment is about 11,500 man-rem; and the occupational exposure is about 5870 man-rem, resulting in a total of about 11 health effects. The predicted number of accidental deaths that would arise from all operations
7-j associated with the foreign spent fuel is about nine.

B.7 Case F-2 - Fuel Shipped to U.S. - Later Reprocessed in U.S. — Plutonium and Uranium Returned (Option 3 Fuel Schedule)

In Case F-2, the foreign countries identified as participating in the Option 3 fuel schedule are assumed to each agree to ship all or part of their spent fuel to the U.S. for storage. This case could also be applied to the Option 2 fuel schedule. The U.S. Government provides ISFS facilities and a geologic repository for storage of U.S. and foreign spent fuel. The geologic repository will become available in the year 1985, at which time limited amounts of spent fuel will be stored in the repository.
6-b (As in other cases, it is recognized that startup of the geologic repository probably will not be achieved by the year 1985.)

A decision is assumed to be made in the year 1990 that the U.S. will reprocess both the U.S. and foreign spent fuel. The plutonium and uranium recovered from the foreign spent fuel will be returned to countries outside sensitive regions for recycling. The reprocessing waste will be disposed of in the U.S. geologic repository. Although contrary to present U.S. policy, this case is included for completeness under the NEPA process.

A decision to reprocess spent fuel and to return mixed-oxide fuel containing plutonium would require that adequate safeguards be available to meet the nonproliferation objectives of the U.S.

B.7.1 Effects of Nonproliferation Policy (Case F-2)

In Case F-2, the U.S. is assumed to decide in the year 1990 to reprocess domestic and foreign spent fuel by using a proliferation-resistant technology. Recovered uranium and plutonium are returned to countries originally owning the spent fuel in a form and under conditions that meet U.S. nonproliferation objectives. Such a course of action represents an extension of the October 1977 spent fuel storage offer. The offer provides that if the U.S. reprocesses foreign spent fuel, the foreign countries that provided the fuel will be given compensation for any net fuel value or will be provided with proliferation-resistant fabricated fuel.

Among the nonproliferation conditions that will apply, plutonium-containing fuel will not be returned to sensitive regions, where its presence would contribute to increased international tensions, unless suitable arrangements for its use could be made; instead, countries in such sensitive regions could be offered compensation for their spent fuel or equivalent value in fresh fuel containing slightly enriched uranium. In all other cases, fuel would be fabricated in the U.S. by using proliferation-resistant technology and returned for immediate use in national reactors. No stockpiling of unirradiated plutonium-bearing fuels would be permitted.

The Case F-2 scenario would depend upon the availability of reprocessing services in the United States. If no facilities are ready for operation when the U.S. makes a decision to reprocess the spent fuel, then six to ten years would be required to construct and license these facilities. In the interim, those considerations discussed under Case E governing international demand for plutonium-bearing fuels would determine in part how many countries would be willing to continue storing spent fuel in the United States. Storage would depend upon availability of reprocessing services and how many nations would prefer to arrange for reprocessing services elsewhere.

This approach would offer some nonproliferation benefits. Reprocessing of foreign spent fuel would be confined to the U.S., thereby discouraging the development of foreign reprocessing capability. A ban on fuel stockpiling in receiving countries would reduce the possibilities for diversion of material potentially usable in nuclear explosive devices. In the context of a U.S. decision to reprocess, this approach would offer countries that originally shipped spent fuel to the U.S. access to a potentially valuable source of fuel in return for pledges not to construct sensitive national facilities.

However, this approach would also present serious proliferation risks. Differential treatment might discourage countries in sensitive regions from taking advantage of the U.S. offer to store spent fuel. The benefits of potentially proliferation-resistant technologies for reprocessing and recycle remain unproved. Many nations would regard a U.S. decision to reprocess, coupled with a ban on foreign reprocessing, as discriminatory and unacceptable. The result might cause some countries to resort to national reprocessing facilities as an alternative to shipping spent fuel to the U.S.

B.7.2 Other Major Environmental Effects (Case F-2)

The major environmental effects of Case F-2 (other than effects on U.S. nonproliferation policy) are given in Tables III-15 through III-17. Table III-15 gives the effects on the U.S. and global commons, and Table III-16 gives the effects on the world. A breakdown of the effects due to the different operations associated with interim storage and with disposition facilities is given in Tables III-15 and III-16.

All operations involving the foreign spent fuel except for transportation, cask loading onto ships in the foreign countries, and transportation of spent fuel containing the plutonium and uranium from the foreign fuel back to foreign countries are carried out in the United States. The contribution of the effects of these transportation activities outside the U.S. and global commons to the total effects is quite small (5% or less); thus, the effects to the U.S. and global commons and to the world differ only slightly, as was also observed in Case F-1. These effects are summarized in Table III-17.

The population whole body dose commitment to the world is
about 11,500 man-rem; and the occupational exposure is about 6,000
7-j man-rem, resulting in a total of about 12 health effects. The
predicted number of accidental deaths is about 11.

B.8 Case G - Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 2 Fuel Schedule)

C In Case G, the alternative preferred by DOE, the U.S. offer
to accept foreign spent fuel for storage is assumed to be implemented for the Option 2 fuel schedule. This schedule includes nations in sensitive regions and a limited number of smaller countries. A decision is also assumed to be made in the year 1990 to dispose of the foreign fuel received in the U.S., along with U.S. spent fuel, in a U.S. geologic repository. Case G is analyzed, assuming the U.S. geologic repository becomes available in the year 1985, and at that time, storage of some of the spent
6-b fuel will begin in the repository. (It is recognized that startup
of the geologic repository will probably not be achieved by the year 1985.) This case is also analyzed, assuming the startup of the geologic repository is delayed ten years until the year 1995.

This case is similar to Case D, discussed in Section III B.5 and Case H discussed in Section III B.9., except for the amount of foreign spent fuels received by the United States. In Case D, the U.S. offer is assumed to be made to countries included in this case (Case G - countries in sensitive regions and a limited number of smaller countries) and in addition to a few larger, industrialized non-nuclear weapons countries (Option 3 fuel schedule). In Case H, the offer is assumed to be made only to countries in sensitive regions (Option 1 fuel schedule).

TABLE III-15

Major Environmental Effects to the U.S. and Global Commons in Case F-2[a]

Facility or Operation	*Population Whole Body Dose Commitment, man-rem*			*Occupational Whole Body Exposure, man-rem*			*Health Effects from Population Dose Commitment and Occupational Exposure*[b]			*Accidental Deaths*		
	Interim Operations	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*
Transportation	37	45	82	250	270	520	0.19	0.20	0.39	1.4	1.9	3.3
7-j ISFS	960	-[c]	960	260	-	260	0.77	-	0.77	0.4	-	0.4
FRP-MOX Plant	-	10,290	10,290	-	4580	4580	-	9.5	9.5	-	2.3	2.3
Geologic Repository	-	19	190	-	700	700	-	0.62	0.62	-	4.6	4.6
Total	1000	10,400	11,500	510	5550	6060	0.96	10.3	11.3	1.8	8.8	10.6
Mining and Milling	-	-	-	-	-	-	-	-	-	-	-	-

a. Fuel shipped to the U.S. and later reprocessed in the U.S. — Pu and U returned (Option 3 Fuel Schedule).

b. Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

TABLE III-16

Major Environmental Effects to the World in Case F-2[a]

		Population Whole Body Dose Commitment, man-rem			*Occupational Whole Body Exposure, man-rem*			*Health Effects from Population Dose Commitment and Occupational Exposure*[b]			*Accidental Deaths*		
	Facility or Operation	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*
E	Transportation	37	50	7	320	350	670	0.23	0.27	0.50	1.4	2.2	3.6
7-j	ISFS	960	-[c]	960	260	-	260	0.77	-	0.77	0.4	-	0.4
	FRP-MOX Plant	-	10,290	10,290	-	4580	4580	-	9.5	9.5	-	2.3	2.3
	Geologic Repository	-	190	190	-	700	700	-	0.62	0.62	-	4.6	4.6
	Total	1000	10,500	11,500	580	5600	6210	1.0	10.4	11.4	1.8	9.1	10.9
	Mining and Milling[d]	0	-3×10^{6}[e]	-3×10^{6}[e]	0	-3000[f]	-3000[f]	0	-120[g]	-120[g]	0	-31	-31

a. Fuel shipped to the U.S. and later reprocessed in the U.S. — Pu and U returned (Option 3 Fuel Schedule).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

d. The incremental effects of the reduction in mining and milling requirements for uranium resulting from recycle of the plutonium and uranium from the foreign fuel are shown. The negative signs indicate a decrease in effects.

e. The population dose commitment from mining and milling activities results from inhalation of radon gas. It is expressed in units of man-rem to the lung, rather than man-rem to the whole body.

f. The occupational dose from mining and milling activities results from inhalation of radon gas and of particulates. It is expressed in units of working level months (WLM). A WLM is defined as exposure for 170 hours to air that contains any combination of short-lived radon daughters in one liter that will ultimately produce 1.3×10^{5} MeV of alpha energy or to an equivalent product of concentration and time.

g. 99.75% of the health effects arise from the mining and milling population dose.

TABLE III-17

Summary of Major Environmental Effects for Case F-2[a]

	Total	*Incremental Effect of Reduced Mining and Milling Requirements*[b] *(Not included in total)*
Population Whole Body Dose Commitment, man-rem		
U.S. and Global Commons	11,500	-3×10^{6}[c]
World	11,500	-3×10^{6}[c]
Occupational Whole Body Exposure, man-rem		
U.S. and Global Commons	6060	-3000[d]
World	6210	-3000[d]
Health Effects from Population Dose Commitment and Occupational Exposure[e]		
U.S. and Global Commons	11.3	-120[f]
World	11.4	-120[f]
Accidental Deaths		
7-j U.S. and Global Commons	10.6	-31
World	10.9	-31

a. Fuel shipped to the U.S. and later reprocessed in the U.S. — Pu and U are returned (Option 3 Fuel Schedule).

b. The incremental effects of the reduction in mining and milling requirements for uranium resulting from recycle of the plutonium and uranium from the foreign fuel are shown. The negative signs indicate a decrease in effects.

c. The population dose commitment from mining and milling activities results from inhalation of radon gas. It is expressed in units of man-rem to the lung, rather than man-rem to the whole body.

d. The occupational dose from mining and milling activities results from inhalation of radon gas and of particulates. It is expressed in units of working level months (WLM). A WLM is defined as exposure for 170 hours to air that contain any combination of short-lived radon daughters in one liter that will ultimately produce 1.3×10^{5} MeV of alpha energy or to an equivalent product of concentration and time.

C *e.* Serious somatic and genetic health effects were calculated from radiation doses, assuming a linear dose-health 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 Volume 2 for more detail on methodology used in determining health effects.)

f. 99.75% of the health effects arise from the mining and milling population dose.

B.8.1 Effects on U.S. Nonproliferation Policy (Case G)

The nonproliferation effects for Case G are discussed in detail in Section II D.2 along with those for Cases D and H (in Sections II D.3 and II D.1). The less-comprehensive nature of the offer in this case, compared with Case D, may cause some nations to reprocess their spent fuel prematurely. If these nations elect to reprocess spent fuel, then they will probably be less inclined to participate in multinational cooperation to develop solutions to the spent fuel storage problem that meet the objectives of the U.S. nonproliferation policy. On the other hand, these countries may be motivated to develop solutions for storage of their spent fuel which are acceptable from the nonproliferation standpoint.

Regardless of the reaction of these nations to their exclusion from the U.S. offer, a larger amount of spent fuel storage would have to be arranged for in foreign locations by these countries than was arranged for in Case D. This increased storage is undersirable because of nonproliferation objectives.

B.8.2 Other Major Environmental Effects (Case G)

The major environmental effects of Case G (other than effects on U.S. nonproliferation policy) are given in Tables III-18 through III-20, assuming startup of the U.S. geologic repository in the years 1985 and 1995. Table III-18 gives the effects on the U.S. and global commons, and Table III-19 gives the effects on the world.

Table III-20 summarizes the effects on the U.S. and global commons and on the world. All operations involving the foreign spent fuel, except for maritime transportation and cask loading onto ships in the foreign countries are carried out in the United States. Thus, the effects on the U.S. and global commons and on the world are the same except for those associated with loading spent fuel casks containing foreign spent fuel onto the ship, and this makes a slight contribution to the total (10% or less).

The whole body dose commitment to the population is about 200 man-rem, if the U.S. geologic repository becomes available in the year 1985 and 1080 man-rem if the repository becomes available in the year 1995. The increase results from the interim storage of a larger amount of spent fuel for a longer time because the geologic repository is not available for disposition of spent fuel. Similarly, the occupational dose increases from about 250 man-rem to about 560 man-rem if the repository is delayed from the year 1985 to the year 1995. The combined population and occupational doses result in less than one health effect for 1985 repository and about one health effect for 1995 geologic repository startup.
7-j Approximately one to two accidental deaths are expected for repository startup either in the years 1985 or 1995.

TABLE III-18

Major Environmental Effects to U.S. and Global Commons in Case G[a]

	Facility or Operation	Population Whole Body Dose Commitment, man-rem			Occupational Whole Body Exposure, man-rem			Health Effects from Population Dose Commitment and Occupational Exposure[b]			Accidental Deaths		
		Interim Operations	Disposition Activities	Total	Interim Operations	Disposition Activities	Total	Interim Operations	Disposition Activities	Total	Interim Operations	Disposition Activities	Total
	1985 Startup of Geologic Repository												
	Transportation	10	-[c]	10	60		69	0.05	-	0.34	0.34		0.34
7-j	ISFS	160	-	160	68	-	68	0.14	-	0.04	0.13	-	0.13
	FRP-MOX Plant	-	-	-	-	-	-	-			-	-	-
7-j	Geologic Repository	-	28	28	-	90	90	-	0.09	0.09	-	0.66	0.66
	Total	170	28	198	138	90	228	0.19	0.09	0.28	0.47	0.66	1.1
	1995 Startup of Geologic Repository												
	Transportation	14.5	-	14.5	79	-	79	0.06	-	0.06	0.41	-	0.41
7-j	ISFS	1023	-	1023	370	-	370	0.87	-	0.87	0.41	-	0.41
	FRP-MOX Plant	-	-		-			-	-	-	-	-	-
7-j	Geologic Repository	-	38.9	39	-	90	90	-	0.09	0.09	-	0.66	0.66
	Total	1040	39	1080	450	90	540	0.93	0.09	1.02	0.82	0.66	1.5

a. Fuel shipped to the U.S. for storage and later disposed of in the U.S. geologic repository (Option 2 Fuel Schedule).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

TABLE III-19

Major Environmental Effects to the World in Case G[a]

	Facility or Operation	Population Whole Body Dose Commitment, man-rem			Occupational Whole Body Exposure, man-rem			Health Effects from Population Dose Commitment and Occupational Exposure[b]			Accidental Deaths		
		Interim Operations	Disposition Activities	Total	Interim Operations	Disposition Activities	Total	Interim Operations	Disposition Activities	Total	Interim Operations	Disposition Activities	Total
	1985 Startup of Geologic Repository												
	Transportation	10.2	-[c]	10.2	88.3	0	88.3	0.07	-	0.07	0.34	-	0.34
7-j	ISFS	164	-	164	68.4	-	68.4	0.14	-	0.14	0.13	-	0.13
	FRP-MOX Plant	-	0	0	-	0	0	-		-	-	-	-
7-j	Geologic Repository	-	28	28	-	90	90	-	0.09	0.09	-	0.66	0.66
	Total	174	28	202	157	90	247	0.21	0.09	0.30	0.47	0.66	1.1
	1995 Startup of Geologic Repository												
	Transportation	14.5	-	14.5	98	-	98	0.07	-	0.07	0.41	0	0.41
7-j	ISFS	1023	-	1023	370	-	370	0.87	-	0.87	0.41	0	0.41
	FRP-MOX Plant	-	-	-	-	-	-	-	-	-	-	0	0
7-j	Geologic Repository	-	38.9		-	90	90	-	0.09	0.09	-	0.66	0.66
	Total	1040	40	1080	470	90	560	0.94	0.09	1.03	0.82	0.66	1.5

a. Fuel shipped to U.S. for storage and later disposed in the U.S. geologic repository (Option 2 Fuel Schedule).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operations indicated in the first column is not involved in the type of activity listed above the dash.

TABLE III-20

Summary of Major Environmental Effects for Case G[a]

	Startup Date of Geologic Repository	
	1985	*1995*
Population Whole Body Dose Commitment, man-rem		
U.S. and Global Commons	198	1080
World	202	1080
Occupational Whole Body Exposure, man-rem		
U.S. and Global Commons	228	540
World	247	560
Health Effects from Population Dose Commitment and Occupational Exposure[b]		
U.S. and Global Commons	0.28	1.02
World	0.30	1.03
Accidental Deaths		
7-j U.S. and Global Commons	1.1	1.5
World	1.1	1.5

a. Fuel shipped to the U.S. for storage and later disposed of in a U.S. geologic repository (Option 2 Fuel Schedule).

C *b.* Serious somatic and genetic 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 heal effects are included in these lines along with those caused by the whole body dos (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

B.9 Case H - Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 1 Fuel Schedule)

In Case H, the U.S. offer to accept foreign spent fuel for storage is assumed to be made only to countries in sensitive regions (Option 1 fuel schedule). A decision is also assumed to be made in the year 1990 to dispose of the foreign fuel received in the U.S., along with U.S. spent fuel in the U.S. geologic repository. Case H is analyzed, assuming the U.S. geologic repository becomes available in the year 1985; and at that time,
6-b storage of some of the spent fuel begins in the repository. (It is recognized that startup of the geologic repository will probably not be achieved by the year 1985.) This case is also analyzed, assuming initial operation of the geologic repository begins in the year 1995, a delay of ten years.

This case is like Cases D and G (discussed in Sections III B.4 and III B.8) except for the foreign countries that are assumed to receive an offer from the U.S. to store their spent fuel. In Case G, the U.S. offer is assumed to be made to the countries included in this Case H and in addition, to a limited number of smaller countries. Case D expands the countries included in the offer by including a few larger, industrial non-nuclear weapons countries.

B.9.1 Effects on U.S. Nonproliferation Policy (Case H)

The nonproliferation effects of Case H are discussed in more detail in Section II D.1 along with those for Cases D and G (in Section II D.2 and II D.3). Removal of spent fuel from countries in sensitive regions will increase confidence that nonproliferation obligations will be observed in these regions and will reduce the risk of separated plutonium being introduced. However, the exclusion of countries not in sensitive regions may be viewed by these countries as discriminatory. This exclusion will also result in a large amount of spent fuel storage remaining in these regions, and may increase the likelihood of premature reprocessing as a solution to the fuel storage problem.

B.9.2 Other Major Environmental Effects (Case H)

The major environmental effects of Case H (other than effects on U.S. nonproliferation policy) are given in Tables III-21 through III-23, assuming startup of the U.S. geologic repository in the years 1985 and 1995. Table III-21 gives the effects on the U.S. and global commons, and Table III-22 gives the effects on the world. Table III-23 summarizes the effects on the U.S. and global commons and on the world from all operations involving the foreign spent fuel.

TABLE III-21

Major Environmental Effects to the U.S. and Global Commons in Case H[a]

	Facility or Operation	*Population Whole Body Dose Commitment, man-rem*			*Occupational Whole Body Exposure, man-rem*			*Health Effects from Population Dose Commitment and Occupational Exposure*[b]			*Accidental Deaths*		
		Interim Operations	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*
	1985 Startup of Geologic REpository												
	Transportation	5.1	-[c]	5.1	33.7	-	33.7	0.025		0.025	0.18	-	0.18
7-j	ISFS	42	-	42	39	-	39	0.05	-	0.05	0.04	-	0.04
	FRP-MOX Plant	-	0	0	-	0	0	-	0	0	-	-	-
7-j	Geologic Repository	-	20	20	-	45	45	-	0	0.047	-	0.34	0.34
	Total	47	20	67	73	45	118	0.08	0.04	0.12	0.22	0.34	0.56
	1995 Startup of Geologic Repository												
	Transportation	7.2	-	7.2	39.5	-	39.5	0.031	0	0.031	0.19	0	0.19
7-j	ISFS	541	-	541	150	-	150	0.43	-	0.43	0.19	-	0.19
	FRP-MOX Plant	-	0	0	-	0	0	-	0	0	-	0	0
7-j	Geologic Repository	-	18	18	-	45	45	-	0.046	0.046	-	0.34	0.34
	Total	550	18	570	190	45	235	0.46	0.05	0.51	0.38	0.34	0.72

a. Fuel shipped to U.S. for storage and later disposed of in a U.S. geologic repository (Option 1 Fuel Schedule).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

TABLE III-22

Major Environmental Effects to the World in Case II[a]

	Facility or Operation	Population Whole Body Dose Commitment, man-rem			Occupational Whole Body Exposure, man-rem			Health Effects from Population Dose Commitment and Occupational Exposure[b]			Accidental Deaths		
		Interim Operations	Disposition Activities	Total	Interim Operations	Disposition Activities	Total	Interim Operations	Disposition Activities	Total	Interim Operations	Disposition Activities	Total
	1985 Startup of Geologic Repository												
	Transportation	5.1	-[c]	5.1	42.7	-	42.7	0.026		0.026	0.18	-	0.18
7-j	ISFS	42	-	42	39	-	39	0.057	-	0.057	0.04	-	0.04
	FRP-MOX Plant	-	-	-	-	0	0	-			-	-	-
7-j	Geologic Repository	-	20	20	-	45	45	-	0.047	0.047	-	-	
	Total	47	20	67	82	45	127	0.08	0.05	0.13	0.22	0.34	0.56
	1995 Startup of Geologic Repository												
	Transportation	7.2		7.2	49.5	0	49.5	0.037	0	0.037	0.19	0	0.19
7-j	ISFS	541	-	541	150	-	150	0.434	-	0.434	0.19	-	0.19
	FRP-MOX Plant	-		-	-	0	-	-	0	0	-	0	0
7-j	Geologic Repository	-	18	18	-	45	45	-	0.046	0.046	-	0.34	0.34
	Total	550	18	570	200	45	245	0.47	0.05	0.52	0.38	0.34	0.72

a. Fuel shipped to the U.S. for storage and later disposed of in a U.S. geologic repository (Option 1 Fuel Schedule).

C *b.* Serious somatic and genetic 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 under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

TABLE III-23

Summary of Major Environmental Effects for Case H[a]

	Startup Date of Geologic Repository 1985	1995
Population Whole Body Dose Commitment, man-rem		
U.S. and Global Commons	67	570
World	67	570
Occupational Whole Body Exposure, man-rem		
U.S. and Global Commons	118	235
World	127	245
Health Effects from Population Dose Commitment and Occupational Exposure[b]		
U.S. and Global Commons	0.12	0.51
World	0.13	0.52
Accidental Deaths		
7-j U.S. and Global Commons	0.56	0.72
World	0.56	0.72

a. Fuel shipped to U.S. for storage — later disposed of in U.S. geologic repository (Option 1 Fuel Schedule).

C *b.* Serious somatic and genetic 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 Volume 2 for more detail on methodology used in determining health effects.)

These operations are carried out in the U.S., except for maritime transportation and cask loading onto ships in the foreign countries. Thus, the effects on the U.S. and global commons and on the world are the same, except for those associated with loading spent fuel casks containing foreign spent fuel onto the ship, and this makes a slight contribution to the total (10% or less).

The whole body dose commitment to the population is about 70 man-rem if the U.S. geologic repository begins operation in the year 1985 and about 570 man-rem if the repository begins operation in the year 1995. The increase results from interim storage of a
C larger amount of spent fuel for a longer time because the geologic repository is not available for disposition of spent fuel. Similarly, the occupational exposure increases from about 130 man-rem to about 250 man-rem if the repository is delayed from the years 1985 to 1995. The combined population and occupational doses result in less than one health effect for the year 1985 or 1995
7-j geologic repository startup. Less than one accidental death is predicted for repository startup in the year 1985 or 1995.

C. Radiation Effects from Abnormal Events

In this section, the releases of radioactive materials to the environment is from postulated accidents at fuel cycle facilities and during transport and are assessed and expressed in terms of the maximum dose commitment and risk that exists for a hypothetical member of the public. For each of the postulated accidents, a credible release of radionuclides is assumed and a maximum individual dose is calculated. Finally, the risk to the individual receiving the maximum dose is given for each accident. This risk is the product of the calculated consequence (expressed as 50-year dose commitment) and the probability of the event (expressed as expected number of events over the entire campaign).

A wide range of postulated accidents is analyzed. Releases of radionuclides from accidents classified as operating incidents are included in the normal radiological releases given in Section III B and in Reference 1 and Volume 2. Probable accidents
8-b for each facility are discussed in the following sections. No near-term biological effects of any significance are expected from any of the accidents analyzed. Table III-24 summarizes the risks for all cases for the foreign fuel increment. The risk shown is conservatively estimated by assuming that the maximum individual adjacent to the facility of maximum risk is also located adjacent to the transportation route into that facility; therefore, the facility and transportation risks are added. The composite risk is quite small for each case.

TABLE III-24

Summary of Maximum Individual Dose Risk for All Cases

Case Description		Maximum Individual Dose Risk, mrem/campaign		
		Body	Bone	Thyroid
Fuel Remains in Foreign Countries (Option 3 Fuel Schedule)	A,B&C	6×10^{-1}	1×10^{1}	3×10^{0}
Fuel Shipped to U.S. for Storage – Later Disposed of in U.S. Geologic Repository (Option 3 Fuel Schedule)	D	4×10^{-1}	2×10^{0}	1×10^{0}
Fuel Shipped to U.S. – Later Returned for Reprocessing (Option 3 Fuel Schedule)	E	6×10^{-1}	1×10^{1}	3×10^{0}
Fuel Shipped to U.S. – Later Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule)	F-1	6×10^{-1}	1×10^{1}	3×10^{0}
Fuel Shipped to U.S. – Later Reprocessed in U.S. – Pu and U Returned (Option 3 Fuel Schedule)	F-2	6×10^{-1}	1×10^{1}	3×10^{0}
Fuel Shipped to U.S. for Storage – Later Disposed of in U.S. Geologic Repository (Option 2 Fuel Schedule)	G	1×10^{-1}	6×10^{-1}	3×10^{-1}
Fuel Shipped to U.S. for Storage – Later Disposed of in U.S. Geologic Repository (Option 1 Fuel Schedule)	H	6×10^{-2}	3×10^{-1}	2×10^{-1}

E

8-a Population dose exposures for these accidents were not prepared in this generic EIS due to the very uncertain results that would accrue from the many assumptions that would have to be made:

- 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 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.

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.1 ISFS Facilities

Two low-probability accidents that could result in offsite release of radionuclides have been identified — tornadoes and criticality events. These are discussed in Volume 2. Since the foreign fuel will only increase these risks slightly, this volume will not discuss these in any more detail. The dose and risk to the maximum individual resulting from these low-potential accidents are given in Tables III-25 and III-26.

TABLE III-25

Maximum Individual Dose from Release Associated with Extreme Abnormal Events

	Event	*Maximum Individual 50-year Dose Commitment, mrem/accident*		
		Body	*Bone*	*Thyroid*
	ISFS Basin			
E	Tornado	5.7×10^{-3}	2.7×10^{-2}	-
E	Criticality	2.0×10^{1}	9.7×10^{-4}	1.3×10^{0}
	Geologic Repository			
	Explosion and Fire	9.9×10^{-2}	2.9×10^{-3}	3.8×10^{-1}
	Transporter Collision	9.4×10^{-3}	1.1×10^{-4}	3.8×10^{-2}
	Dropped Canister	9.4×10^{-3}	1.1×10^{-4}	3.8×10^{-2}
E	Criticality	9.6×10^{0}	3.3×10^{-4}	4.4×10^{1}
	FRP-MOX Plant			
E	Explosion in HLW Concentrator	5.4×10^{0}	9.3×10^{1}	-
	Explosion in Pu Concentrator	1.1×10^{1}	4.8×10^{2}	-
E	Criticality	5.6×10^{0}	1.9×10^{-4}	2.6×10^{1}
	Transportation			
	Spent Fuel Shipment			
	Land Transport	4.0×10^{2}	1.7×10^{4}	-
	Sea Transport	1.6×10^{3}	6.8×10^{4}	-
	HLW Shipment	8.0×10^{2}	1.2×10^{4}	-
	LLW-TRU Shipment	4.0×10^{3}	6.0×10^{4}	-

TABLE III-26

Maximum Dose Risk to an Individual from Extreme Abnormal Event During Entire Campaign for the Foreign Fuel Increment[a]

Event	*Maximum Individual Dose Risk, mrem/campaign*		
	Body	*Bone*	*Thyroid*
ISFS Basin			
Tornado	2×10^{-7}	1×10^{-6}	-[b]
Criticality	7×10^{-4}	4×10^{-8}	5×10^{-5}
Geologic Repository			
Explosion and Fire	3×10^{-1}	8×10^{-3}	1×10^{0}
Transporter Collision	2×10^{-2}	2×10^{-4}	6×10^{-2}
Dropped Canister	3×10^{-8}	4×10^{-10}	1×10^{-7}
Criticality	8×10^{-4}	3×10^{-8}	4×10^{-3}
FRP-MOX Plant			
Explosion in HLW Concentrator	2×10^{-1}	3×10^{0}	-
Explosion in Pu Concentrator	5×10^{-2}	2×10^{0}	-
Criticality	3×10^{-1}	2×10^{-5}	3×10^{0}
Transportation[b]			
Spent Fuel Shipment	6×10^{-2}	2×10^{0}	-
HLW Shipment	1×10^{-3}	2×10^{-1}	-
LLW TRU Shipment	1×10^{-2}	4×10^{0}	-

a. For Option 3 Fuel Schedule.

b. Includes land and sea transportation accidents.

C.2 Geologic Repository

Two groups of accidents are analyzed for the geologic repository in this volume. These are accidents or events postulated to occur during operation of the repository and those that may occur after the repository has been shut down and the waste terminally stored. These events are discussed briefly in this section. Accidents in the geologic repository are treated more completely in a generic environmental impact statement on commercial waste management[6] prepared by the Department of Energy.

C.2.1 Abnormal Events During Operation of the Repository

Abnormal events are those events that can be postulated to occur during the operational phase of the repository but would occur with a low probability. These include:

- Canister dropped down the mine shaft
- Criticality
- Explosion and fire in the repository
- Collision of vehicles transporting spent fuel or waste
- Tornado
- Earthquake
- Airplane crash

Surface facilities handling the spent fuel and reprocessing waste at a geologic repository are Category 1 structures designed to withstand most credible accidents and natural events. The facility therefore mitigates the effects of tornadoes, earthquakes, airplane crash, etc.

C.2.1.1 Canister Dropped Down Mine Shaft

A fuel element canister is assumed to drop down the mine shaft with rupture and release of the gaseous radionuclides and some particulate activity contained in the fuel cladding gap. The dose and risk to the maximum individual are given in Tables III-25 and III-26, respectively.

C.2.1.2 Criticality

A criticality incident in the geologic repository is an unlikely event. Safe spacing of spent LWR fuel is assured by procedural control, the physical space required by the encapsulated fuel, the design of the facility, and the spacing requirements for disposal in geologic repositories. (A criticality incident from handling CANDU fuel or reprocessing waste is not considered to be credible.) In a quarter century (some 500 plant years of experience) of handling spent fuel and products obtained from these spent fuels, only four major criticality events have occurred. Two of these occurred in plutonium scrap recovery operations and two in highly enriched uranium operations. The magnitude of these criticality events ranged from 1.3×10^{17} to 4×10^{19} fissions. A criticality accident of 1×10^{18} fissions assumed in this analysis involves four PWR assemblies; the cladding and canisters are assumed to be ruptured on all fuel elements, releasing the fuel-cladding gap activity. The consequence and risk resulting from this accident are given in Tables III-25 and III-26, respectively.

C.2.1.3 Explosion and Fire in the Repository

The most likely cause of an explosion and fire that would involve radionuclides in the repository operation would be explosion of a spent fuel transporter fuel tank. If the explosion and fire involve the spent fuel, the canister would be heated; and if it and the fuel cladding rupture, a small release could be postulated. Only fission product gas would escape from the repository. The particulates would be removed by the two-stage HEPA ventilation filters. Gaseous radionuclides lost in such an accident would be released through the 110-m (360-ft) stack. Doses and risk to the maximum individual resulting from this explosion and fire are given in Tables III-25 and III-26, respectively.

C.2.1.4 Collision of Vehicles Transporting Spent Fuel

If a transporter carrying spent fuel were to collide with another vehicle and rupture both the cask and the spent fuel, then gaseous radionuclides in the fuel-cladding gap might escape. The probability of this collision breaching the spent fuel cask within the geologic repository is extremely low because of the low vehicle speed within the repository. The accident was, however, assumed to occur with the same probability as truck collision in surface activities; and the cask and fuel were assumed to be damaged. The consequence and risk of the maximum individual resulting from the collision are given in Tables III-25 and III-26, respectively.

C.2.2 Abnormal Events After Terminal Storage

Several studies[7-12] have been made to investigate the consequences and risks of the long-term effects of storage of reprocessing waste. A comprehensive risk analysis has not yet been published for waste repositories, but the above studies generally conclude that both near-term and long-term risks for the types of geologic repositories described in this volume will be small. The long-term risks (greater than 1000 years) will be about the same as that from natural uranium and radium in the earth's crust. As can be seen in Figure III-1, within a thousand years, the hazardous components of nuclear waste decay to relative toxicity levels lower than those of natural uranium from which the waste was derived. The hazards of disposal of reprocessing waste are smaller than those of spent fuel waste due to the removal of plutonium during reprocessing. Spent fuel requires on the order of 100,000 years to reach a toxicity level equivalent to reprocessing waste after 1000 years. At this point, the spent fuel becomes essentially equivalent in toxicity to the natural uranium ore from which the spent fuel was prepared.

The generic geologic repository presents multiple lines of defense against release (i.e., very stable waste form, durable containers, and a stable geologic repository deep in the ground). The result of the investigation at the site of the 1.8-billion-year-old Oklo natural reactor in Gabon, Africa, indicates the ability of geologic formations to retain radioactivity, especially long-lived actinides even when not located deep within geologic formations. However, absolute confidence in the integrity of the repository over the next few hundred thousand years cannot be assumed, and it seems desirable to postulate conditions that may result in failure of the repository and to determine the consequences and risks of the stored wastes.

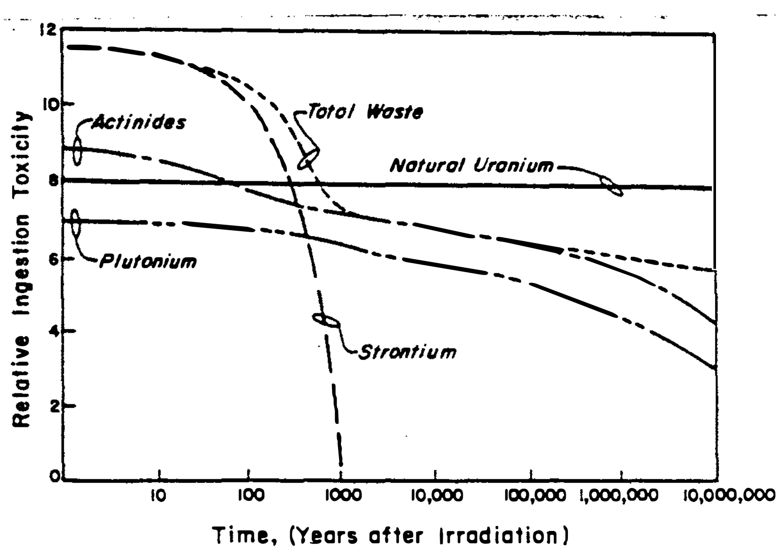

FIGURE III.1. Relative Ingestion Toxicity[13]

Basically there are three generic types of conditions which could breach the repository and release any of its contents. These are

- Direct release of contents to the atmosphere or hydrosphere through such mechanisms as volcanic activity, meteorite impact, or detonation of a large nuclear weapon. On a much longer time scale, these mechanisms include denuding the earth to the depth of the repository by erosion or glaciation.

- Release by water that has entered the repository as a result of flooding or seepage following breaching of overlying rock. Breaching of the rock may occur from fracturing by faulting, nearby impact of meteorite or detonation of a nuclear weapon, thermal stresses due to decay heat from the radioactive waste, mechanical stress resulting from adjustment of repository rock following excavations, or by failure of shaft and/or borehole seals.

- Release through man-made intrusions from exploratory drilling, archeological exploration or solution mining of salt or phosphates or as a result of cavern construction for storage of E oil, industrial wastes, compressed gas, etc.

From these generic breach conditions, several specific scenarios were selected and analyzed to show the range of consequences and risk that may result. These scenarios include:

- Meteorite impact penetrating to the waste bearing stratum

- Fracturing through rock overlying the repository by faulting followed by flooding

- Exploratory drilling through a waste canister.

Table III-27 summarizes the consequences and risk from these hypothetical events. These scenarios are given to provide a reasonable analysis on the severity of accidents which may breach the repository after operations at the repository have ceased and the repository has been backfilled and decommissioned. These individual results are not assumed necessarily to be the events most likely to occur. As can be seen, the consequences of repository failure caused by meteorite impact, 50 years after repository closure, is large (4-5 x 10^6 rem to the whole body); but the
E risk is negligibly small (1.0 x 10^{-6} rem/yr) because of the very low probability. The largest risk is from drilling into the repository, but it is also small (<9 x 10^{-2} rem/yr).

TABLE III-27

Summary of Abnormal Events after Terminal Storage (70-year Dose Commitment)
Maximum Individual Whole Body Dose

	50 Years After Repository Closure		*1000 Years After Repository Closure*	
Form of Waste →	*Spent Fuel*	*Reprocessing Waste*	*Spent Fuel*	*Reprocessing Waste*
Consequence, rem/event				
Meteorite	3.9×10^{6}	5.1×10^{6}	3.6×10^{2}	2.3×10^{2}
Faulting	1.4×10^{2}	3.4×10^{2}	9.0×10^{1}	5.0×10^{-1}
Man Drilling	*a*	*a*	9.4×10^{2}	9.9×10^{3}
Risk, rem/year				
Meteorite	7.8×10^{-7}	1.0×10^{-6}	7.2×10^{-11}	4.6×10^{-11}
Faulting	2.8×10^{-11}	6.8×10^{-11}	1.8×10^{-11}	1×10^{-13}
Man Drilling	*a*	*a*	8.5×10^{-3}	8.9×10^{-2}

a. Not Analyzed.

C.3 Reprocessing — MOX Fuel Fabrication Facility

The fuel reprocessing and MOX fuel fabrication facilities are housed in Category 1 structures of reinforced-concrete which are built on reinforced-concrete foundations. These structures are constructed to undergo large deformation loads that might be experienced in credible accidents, without failure, including design basis tornadoes and earthquakes.

Low probability accidents that could result in offsite releases of radionuclides at collocated FRP-MOX plants are discussed briefly in the following paragraphs. These include:

- Criticality events
- Explosions in the HLW concentrator
- Explosions in the plutonium concentrator.

The credible range of energy release in explosions, fires, and pressure surges from criticality accidents is not expected to breach the facility structures. Any release of radioactive material will therefore be from the 100-m (330-ft) stack on the site; filters located remotely from the accident are assumed to remain intact and reduce the amount of material released.

Criticality

Equipment and processes in reprocessing and PuO_2 conversion plants are designed to reduce the probability of a criticality C accident to a very low value. Physically spacing the fuel elements in storage racks at the reprocessing plant assures safe spacing in storage basins, even when one spent fuel assembly is dropped. Process systems and controls are designed to prevent assembly of an unsafe array. For this analysis, a criticality accident is postulated in which a burst of 10^{18} fissions occurs. For comparison, criticality accidents in DOE facilities summarized in WASH 1192[14] resulted in from 3×10^{15} to 5×10^{17} fissions for metal systems in air and from 1.1×10^{16} to 4×10^{19} fissions for liquid systems.

All volatile fission products formed during the excursion are assumed to be released to the atmosphere through the stack. Airborne particulates in a criticality event in a reprocessing facility make a negligible contribution to the dose commitment. However, if a criticality accident occurs in the MOX fabrication facility, 500 g of plutonium is assumed to be airborne within the facility and 5×10^{-4} mg of plutonium is assumed to be released to the environment. The dose and risk to the maximum individual resulting from criticality excursions are given in Tables III-25 and III-26.

HLW Concentrator Explosion

During operation of the solvent-extraction process in the reprocessing plant, solvent degradation products are generated and may be carried over into the waste streams. These nitrated degradation products have caused HLW waste concentrator explosions in the past because of rapid decomposition. Modern plants install equipment and controls designed to preclude an explosion.

Waste concentrators are installed in highly shielded cells with a volume of 3000 m^3 (100,000 ft^3). The explosion is assumed to release about 600 L (150 gal) of waste solution into the cell as a finely divided mist. A substantial fraction of the mist would rain-out or plate-out on the cell surfaces. Most of the droplets remaining in the air would be removed by the HEPA filters or by the moisture separators upstream of the filters. The material leaving the final filter is assumed to include 420 mg of high level waste. The resulting dose and risk to the maximum individual are given in Tables III-25 and III-26.

Plutonium Concentrator Explosion

The explosion of a plutonium concentrator in the fuel reprocessing plant could result in a release of plutonium to a cell or glove box area. The plutonium processing equipment is usually smaller and is installed in smaller rooms (cells or glove boxes) than the waste concentrator discussed above. The dose commitment from the plutonium concentrator explosion is two to five times greater than that from the waste concentrator explosion, as seen in Table III-25. The dose risk to the maximum individual is about the same, however, because of an expected lower frequency of plutonium concentrator explosions (Table III-26).

C.4 Transportation

A recent NRC study,[15] concluded that the cumulative annual radiological impact was small for shipments of all radioactive materials transported in the U.S. by all modes of transportation. This NRC study also concluded that the radiological dose risk from accidents for all shipments is about one-half percent of the

C dose from all normal transportation. From that study, it can be concluded that U.S. spent fuel assumed to be transported in the year 1985 will cause about 3% of the total radiological impact of the total spectrum of shipments of radioactive materials in the United States. Foreign spent fuel shipments considered in this volume are less than 20% of the estimated U.S. spent fuel shipments, and the radiological risk from accidents during transportation of foreign spent fuel in the U.S. considered in this volume would be very small based upon information given in the NRC study.[15]

The analysis performed for this volume confirms the conclusions of the NRC study. The massive, heavily shielded construction of shipping casks for spent fuel and reprocessing waste are designed to survive severe transportation accidents. A low probability of damage severe enough to release radioactive material from a cask is described in Reference 1 and Volume 2, and the estimated conse-
C quences and risks during transport of foreign fuel cooled four years or longer on land and sea are given in Tables III-25 and III-26. The risks arise primarily from accidents involving rail shipments because most of the spent fuel and almost all the reprocessing wastes are transported by rail. The risk from maritime operations is small compared with rail operations.[1,15,16] Accident
C rates on the open seas are very low, and the radiological risks determined in this volume are small compared with the nonradiological risks of injury and death caused by collision of ships or shipboard fire or explosion.[1]

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. For example, if railroad car carrying a cask containing 0.5-yr cooled fuel in its water-filled cavity is involved in an extreme transportation accident that breaches the cavity releasing the cooling water, the cask temperature will increase. If no emergency action is taken to cool the cask exterior for several days, the whole body dose to an individual may be as high as 120 rems from inhaled
1-f radionuclides.[6] This type of accident 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. (See Section III C.3.2 and Appendix C of Volume 2 of this final EIS for further discussion of this accident.) If receipt of short-cooled (<2-year-cooled) spent fuel from sensitive countries benefits the U.S. nonproliferation objective, this spent fuel could be shipped safely under special arrangements and agreements in existing casks. Therefore, the consequences and risks resulting from transporting of short-cooled spent fuel in casks with water-filled cavities are not included in Tables III-25 and III-26, nor in other parts of this EIS.

C.4.1 Sea Transportation Accidents

No maritime accident has ever occurred that resulted in release of radionuclides from shipping casks. Statistics of maritime accidents have not been compiled as extensively as for land transport, but studies of U.S. Coast Guard accident reports are currently being performed by Sandia Laboratory to identify both frequency and severity of maritime accidents. Preliminary information available from the Sandia study indicates that the frequency of extreme accidents on a per mile traveled basis in sea transport is lower than the frequency of accidents in land transport.

Assumptions made to evaluate the consequence, probability, and risk of maritime accidents for this volume are based upon discussions in NUREG-0170,[15] ERDA-1542,[16] and BNWL-2093.[17] Pertinent information extracted from these references and Reference 1 are summarized in C.4.1.1 for assumed accident scenarios.

C The three most severe maritime accident scenarios considered are discussed in the following sections. These include ship collision, spent fuel cask sinking, and explosion and fire involving these casks. Other accidents that are judged to be of less consequence include:

- Dropped cargo striking cask
- Shifting cargo striking cask
- Ship grounding
- Drifting objects striking the carrier ship
- Interaction of cask with other hazardous cargoes.

C.4.1.1 Ship Collision Breaching Cask

Ships operate at much lower speeds than trucks and trains. In harbors, ship speeds are normally less than 5 mph. On the open seas, the cargo ships transporting spent fuel casks cruise at 20 to 25 knots (23 to 29 mph). In comparison, trucks and trains travel at velocities up to 60 mph in rural areas.

8-e Most of the ship collisions occurred near and in busy harbors or in congested shipping lanes. For example, during the years 1964 through 1974, of 59 collisions occurring on the New York — Rotterdam route, five occurred in New York Harbor or its vicinity; 54 occurred in the English Channel, North Sea, or Rotterdam approach; and none occurred in the open sea.[18]

Cargo ships assumed to transport spent fuel casks will have the capacity to transport the casks in the holds or on decks of the ships with special tiedown fixtures to secure the cask. The hull of the ship and the tiedown fixtures will serve to mitigate forces acting upon the cask in the event of a ship collision.

8-e In view of the lower speed of the cargo ship, particularly in harbors, the cushioning effect of the ship's hull, and cask tiedown fixtures, the probability of cask failure in a maritime accident is expected to be less than the probability of cask failure for land transport. The mass of fully loaded container ships of the 20,000 dead weight ton class is about 27,000 tons. For comparison, the mass of an "average" U.S. train is about 5500 tons. Considering the compensating effects of operational velocities and mass differences between the container ships and trains, the impact and crushing forces are probably similar.

Since sufficient data for ship accidents applicable to spent fuel casks are not currently available and the crush and impact forces are similar in rail and ship accidents, the probability of breaching a cask during sea transport is estimated from rail cask data. The probability of a rail accident being severe enough to possibly breach a spent fuel cask is estimated to be about 10^{-5} (Reference 1). In this volume, that probability is assumed to apply to casks involved in ship collisions. Further, the consequences of breaching a cask are assumed to be about the same as for a similar accident during land transport. The frequency of collision of the cargo ships that would transport the foreign spent fuel is about 10^{-5} to 10^{-6} per trip.[19] Assuming the upper value of 10^{-5} for collision, the probability of a ship collision with breaching of a cask is about 10^{-10} per ship trip.

In the maximum year, about 70 ship trips will be required to transport spent fuel to the U.S.; thus, the probability of a cask breaching in the year of maximum operation is in the order of 10^{-8}. It is assumed that the consequences of cask breaching at sea is similar to the consequences of a rail cask failure in Volume 2 of this EIS and Reference 1, where the dose to the maximum individual would be 0.4 rem/event for spent fuel cooled four years or longer.

Since multiple casks will probably be transported on a single ship, it is assumed in this analysis that four casks on a single ship may be breached. Consequences and risk of a collision resulting in a breach of the shipping casks during ship transport are small as shown in Table III-28 and were included in Tables III-25 and III-26.

TABLE III-28

Maximum Individual Dose and Risk from Releases Associated with Maritime Accidents

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Type of Accident	*Frequency (events/yr)*	*Consequence (rem/event whole body)*	*Risk (rem/yr whole body)*
Collision with Damage to Cask and Release of Radioactive Materials (extreme accidents)	About 10^{-8}	1.6	2×10^{-8}
Submersion of Cask[a]			
- On Continental Shelf	4×10^{-3}	0	0
- Ocean Depths 0.2 to 3.6 km	4×10^{-3}	$<2 \times 10^{-4}$	$<8 \times 10^{-7}$
- Deep Ocean	2×10^{-2}	$<1 \times 10^{-6}$	$<2 \times 10^{-8}$
Fire or Explosion Aboard Ship	4×10^{-3}[b]	0[c]	0[c]

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a. Information from Reference 17 in which a probable loss of the ship is assumed to be $<10^{-3}$ per round trip. Other studies show that this value is very conservative for a well-equipped larger cargo ship.[1,18]

b. From Reference 18.

c. A shipboard fire or explosion is not anticipated to breach a cask containing long-cooled spent fuel.

C.4.1.2 Cask Submersion

If a cask were lost overboard during shipboard loading or unloading, during a maritime accident, or were sunk along with the carrier ship, the cask would be expected to be recovered. Equipment for deep-sea recovery of ships and cask-size objects has been developed and used.[20] Sunken ships have been recovered from depths greater than 5 km (3 mi), and cask-shaped objects have been recovered from steep and unstable walls of marine canyons.[21] Other items have been located and recovered from depths exceeding 6 km (3.8 mi), or about twice the mean ocean depth.[22] The techniques indicated above can be adapted for recovery of a submerged spent fuel cask. A cask dropped in the water during loading or unloading or submerged after an accident in the harbor can be retrieved with existing lift equipment.

No releases from submerged casks would be expected to occur in water depths less than 0.2 km (0.1 mi).[16] This is the typical depth at the edge of the continental shelf. Typical spent fuel casks are designed to maintain containment integrity at internal pressures of 233 to 375 psig.[23] Therefore, spent fuel casks are expected to withstand water pressure if submerged on the continental shelf. If a cask seal were to fail due to excessive pressure in deep water, only the small amount of radioactivity in the cask coolant and gases from perforated cladding of fuel assemblies in the cask cavity would likely be immediately released. Many years later, corrosion of fuel assemblies could slowly release radioactivity. Dispersion of this slightly contaminated coolant and gases in the sea water would pose no problem to the environment even in the immediate vicinity of the leakage. If seafood gathered from the vicinity of the release is consumed, the individual dose is estimated as $<2 \times 10^{-4}$ rem/event.[17]

Even if a cask fails due to extensive external pressure, the fuel assemblies will not necessarily fail. Reactor fuel elements are designed to operate at elevated temperatures and at pressures of about 1000 to 2000 psi. Fuel cladding would not be expected to fail unless water depths of greater than 3.6 km (2.2 mi)[16] were reached. Once the cladding failed, fuel pins would be exposed to sea water and would very slowly corrode. The cask would essentially remain intact and provide adequate protection of the spent fuel until the cask could be retrieved. The consequences of these releases at depths greater than 3.6 km (2.2 mi) was estimated to be $<1 \times 10^{-6}$ rem/event to an individual by using information from Reference 17 and the estimated fraction of seafood taken from depths greater than 3.6 km (2.2 mi) that the maximum individual might consume.

Submersion of a spent fuel cask will occur if a ship sinks. The probability of the loss of a ship is conservatively assumed to be $<10^{-3}$ per round trip.[17] Other studies[1,18] show that this value is conservative by a factor of 10^2 to 10^3 for cargo ships of the 20,000 deadweight ton class that have high quality navigational and electronic gear and a well-trained, highly qualified crew.

8-f In the maximum year, 70 ship loads of spent fuel will be required. Therefore, the loss of a ship transporting spent fuel casks is assumed to have a frequency of 7×10^{-2} events/year. Since the ship will be transporting casks containing spent fuel only during half of the round trip, frequency of loss of a ship while transporting casks with spent fuel is assumed to be about 3.5×10^{-2} per year.

For the assumed shipping lanes, about 10% of the shipping distance will be over the continental shelf, 10% over the ocean where depths vary between 0.2 to 3.6 km (0.1 to 2.2 mi), and 80% over the deep ocean where depths exceed 3.6 km.[17] The estimated frequency of the loss of a ship transporting spent fuel over the continental shelf, the ocean where depths vary between 0.2 to 3.6 km (0.1 to 2.2 mi), and the deep ocean, are shown in Table III-28. This frequency is considered to be conservative because:

- Most accidents with loss of ship occur in congested areas near harbors.[19] In this analysis, uniform distribution of accidents is assumed along the shipping lanes.

- Reference 17 cites statistics that include all vessels over 1800 tons. Other studies[1,18] cite accident statistics from only larger cargo ships and show more than an order of magnitude less probability for loss of ship per round trip.

The consequences shown for cask submersion are conservative since the assumption is made that accidents resulting in cask submersion occur uniformly along the entire transport route. However, most collisions occur in or near harbors,[18] where water depths are much less than 0.2 km (0.1 mi) and the consequences under that condition would be negligible.

C.4.1.3 Maritime Fire and Explosion

All fire scenarios considered for maritime transport are not expected to result in any loss of contents from the spent fuel cask carrying spent fuel cooled about four years or longer. Even in a fire of long duration, the temperature of the spent fuel in the cask is expected to remain well below the temperature that might cause cladding perforation because the spent fuel is cooled for about four years or longer.

8-e Maritime regulations[24] require storage of explosives at a large distance from radioactive materials on a ship. Therefore, since any explosion aboard ship would be expected to occur at distances removed from a spent fuel shipping cask, explosions are not likely to damage the cask. Releases of radionuclides from the cask are therefore not expected for this postulated accident.

C.4.2 Land Transportation Accidents

Foreign spent fuel will be transported within the U.S. by truck and rail in rugged casks specifically designed and tested to ensure retention of the contents during severe transportation accidents. If a cask is involved in moderate or severe accidents, cladding failure may occur, but the cask is expected to remain intact. Extreme accidents, which have a very low probability of occurring, may cause breaching of the cask containment. Unless the cask 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 Reference 1 and Volume 2.

C.4.2.1 Spent Fuel Transportation

The dose to the maximum individual is shown in Table III-25 for an extreme accident resulting in breaching a cask being used to transport spent fuel. The release of radionuclides assumed in this accident is the same to the maximum individual as postulated in Volume 2. The risk from accidents involving foreign spent fuel transport is shown in Table III-26.

C.4.2.2 Reprocessing Waste Transportation

In some cases considered in this volume, the spent fuel is assumed to be reprocessed and the resulting wastes are assumed to be transported to a geologic repository. Accidents associated with reprocessing waste transport are identified in Reference 1. This includes high-level waste, cladding wastes, intermediate-level wastes, low-level transuranic (TRU) wastes, and low-level wastes.

8-e Casks and other packages used for shipment of wastes from any reprocessing plant will be designed to provide protection from high radiation dose rates, containment of radionuclides and, for high-level wastes, dissipation of decay heat. The casks or steel drums and boxes that are placed in Type B overpacks for shipment are designed to retain shielding and containment integrity in virtually all transport accident situations. Licensing requirements for these packages, including tests specified for hypothetical accident conditions, are similar to those for spent fuel casks.

The consequences resulting from severe transportation accidents transporting all types of reprocessing waste show that high-level waste and low-level transuranic wastes impose the largest consequence[1] and risk. Other waste forms have much lower consequences. This volume therefore determines the consequence and risk resulting from transporting only the high-level waste and low-level transuranic wastes as follows:

- <u>High-Level Waste Transportation</u>

  Casks used for high-level waste are expected to be similar to rail casks used to transport spent fuel. As indicated in Reference 1, in an extreme accident high-level waste casks are assumed to be breached in much the same manner as assumed for spent fuel casks. Before a release can occur, this accident must also penetrate the thick wall high-level waste container and fracture the high-level waste form. For an extreme transportation accident, this volume assumes the released fraction is on the order of 10^{-8} of the cask contents.[1]

  The consequences to the maximum individual resulting from this high-level waste accident is given in Table III-25 and the risk for the campaign is given in Table III-26.

- <u>Low-Level Transuranic Waste Transportation</u>

  In this volume, low-level transuranium wastes are assumed to be packaged in steel drums within a solid matrix such as concrete. These waste drums are assumed to be transported in a protective overpack. This overpack protects the drums from impact and thermal stresses during transportation accidents. In an extreme accident, there is a small possibility that the overpack may be breached. Only a small fraction of the matrix containing the wastes would be expected to be crushed into respirable fines which may then migrate through a failed drum and then somehow be transported from the damaged overpack into the environment. The analysis in Reference 1 identifies that the release fraction for such an extreme accident is about 10^{-5}.

8-e In this volume, a load of low-level transuranic waste is assumed to contain about 800 Ci of transuranium isotopes. In an extreme accident, 10% of the solidified waste (concrete waste form) was assumed to be fractured and crushed producing some small particles. From data in DP-1400,[25] about 0.1% of the concrete waste was assumed to be crushed sufficiently to produce respirable size particles by the impact assumed to breach the container. Further, in this volume, it is conservatively assumed that 10% of the crushed concrete particles escape from the damaged drums to the protective overpack and then through a breach in the overpack to the surrounding environment.

The consequences to the maximum individual resulting from a severe accident causing low-level transuranic waste to be released to the environment are given in Table III-25. The risk to the maximum individual for the campaign is given in Table III-26.

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IV. SAFEGUARDS

The transportation, storage, and disposal activities described in this volume involve radioactive and fissionable material that can, under specific circumstances, be misused to attempt to create an unacceptable public risk. Examples of situations that might represent such circumstances and the resulting risk to the public are described in this section together with controls to mitigate these situations.

Both subnational and national (or multinational) safeguards are described in this section. Subnational safeguards include the controls aimed at preventing individuals or groups from stealing or diverting fissionable material or sabotaging nuclear facilities, including ships, trains, or trucks transporting fissionalbe materials. National (or multinational) safeguards are the controls to deter nations from diverting nuclear material for construction of nuclear devices. Safeguard controls address material accountancy and verification.

Risk in the context of the Safeguards Section is the product of the following factors: 1) the probability of a threatening act being attempted, 2) the probability of the act being successful, and 3) the consequence of a successful act to the public.

Measuring the risk to the public, in a purely objective, quantitative way, is not possible because factors involved in determining the frequency of attempt (such as assessing motivation and capability for various types of adversary actions as a function of a potential adversary group) cannot be determined. It is possible, however, to develop and maintain a generally internally consistent system (i.e., to allocate safeguards resources in a manner which results in a general equality of the individual risks from all reasonably possible adversary action sequences) without quantifying the acceptable level of risk or being able to calculate the individual risk for each adversary scenario.

A. Threat

A.1 Threat Definition

Threats involving radioactive and fissionable materials are sabotage and theft with subsequent malevolent acts or diversion of nuclear materials for construction of a nuclear device. Sabotage could occur in storage or reprocessing facilities or during transportation operations. The intent would be to disrupt or destroy and might include a deliberate attempt to disperse radioactive materials to the environment. Theft could be attempted from storage or reprocessing facilities or during transportation. Potential acts subsequent to theft by force or diversion may include:

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- Sabotage with intent to disperse radioactive materials at a location remote from the theft site
- Dispersal of plutonium powders
- Construction of an improvised nuclear device
- Blackmail of governmental entities by threat of sabotage or dispersal of radioactive contaminants in populous areas.

A.2 Methods of Threat Execution

The threats involve both sabotage and theft of nuclear materials in various combinations. The three different methods of achieving the objectives of a saboteur group are 1) dispersal of radioactive contaminants from spent fuel or plutonium powders locally or at some remote location selected by saboteurs, 2) theft of nuclear material with the intent of construction of an improvised nuclear device, and 3) theft of nuclear material for purposes of blackmail by threatened subsequent malevolent acts involving the nuclear material. Each of these three methods are discussed below.

A.2.1 Dispersal of Radioactive Contaminants

Prerequisites for dispersal of radioactive contaminants are 1) access to nuclear materials in storage or reprocessing facilities or during transportation operations, 2) a means of defeating any packaging or containment system, and 3) production of a mechanism capable of dispersing small particulates or radioactive gases from the damaged confinement or packaging system.

Spent or recycled nuclear fuel assemblies consist of a solid, ceramic-type core material encased in metal cladding, and use of an energy-intensive device would be required to crush and pulverize the fuel assembly into small dispersible particles. The energy-intensive device must concurrently damage the containment system of the storage or reprocessing facility or the protective packaging provided during transportation of fuel assemblies.

As discussed in Volume 2 of this final EIS, concurrent damage of fuel assemblies and the confinement or packaging systems cannot be considered impossible. Such an act, if performed in a location with a high-population density, has the potential to produce large releases of materials resulting in radiological and economic impacts on the scale of severe accidents but, to be successful, the act must overcome formidable obstacles imposed by safeguard controls.

If spent fuel were reprocessed and a plutonium powder produced during processing, as assumed in Case A, some of the material could be diverted in the processing facility, removed from the facility, and later dispersed to the environs. Alternatively, spent fuel could be reprocessed, after being stolen, to produce plutonium powders for the purpose of dispersal to the environs.

Obtaining plutonium powder for dispersal (from a reprocessing facility or a clandestine operation after theft of spent fuel) cannot be considered impossible. However, successful diversion of plutonium powder from a reprocessing plant would have to overcome intensive safeguard controls, including monitoring of nuclear materials inventories and the activities of personnel. After theft, clandestine production of plutonium powder would require avoidance of detection by law enforcement authorities searching for the material to recover it.

A.2.2 Construction of Improvised Nuclear Device

Construction of an improvised nuclear device requires a supply of separated plutonium or highly enriched uranium. The current generation of reactor fuels contains low concentrations of uranium-235 and plutonium so that the plutonium separated from the spent reactor fuels is the material of concern to safeguards. Spent fuel itself is not usable for the manufacture of nuclear explosive devices. The plutonium contained in the spent fuel could serve as potential material for nuclear explosives but, first, complicated and potentially hazardous chemical reprocessing is required to separate the plutonium from the fission products and residual uranium. To acquire sufficient plutonium from spent fuel would require the handling of a highly radioactive material and the availability of a specialized chemical processing facility appropriately designed with remote handling equipment and shielding to separate the nuclear material from fission products. Plutonium in sufficient quantities could represent a potentially serious criticality problem that must be considered in any fabrication operation. In addition to the hazards in handling nuclear materials, the fabrication and assembly of high explosive material, detonators, and electrical firing systems for an improvised nuclear device require extreme caution as well as significant expertise.

A general consensus is that the fabrication of an improvised nuclear device requires a broad range of skills and resources. Disagreement arises with respect to the specific level and resources required, as well as to the difficulty of acquiring the nuclear material and successfully fabricating a nuclear explosive without detection or serious accident to the individuals involved. There is also considerable uncertainty concerning the yield that might be achieved by such a device.

A number of complicated and high-risk steps would be
C required of any group contemplating a malevolent act involving the construction of an improvised nuclear device. While each of these steps for fabricating an improvised nuclear device cannot be considered impossible, they must be recognized as posing formidable obstacles, each of which must be successfully overcome without detection or serious accident to the individual involved.

C A.2.3 <u>Theft for Blackmail</u>

Theft of radioactive and fissionable materials requires the overpowering of safeguard forces at nuclear facilities or highjacking of material during transportation. After the theft, the threat group could intimidate or blackmail municipalities or other local government groups by threatening sabotage or some other method of dispersal of the radioactive contaminants in populous areas as discussed in Section A.2.1. Theft could possibly be for construction of an improvised nuclear device as discussed in
10-c Section A.2.2 or for sale of the material to a group contemplating construction of such a device.

C A.3 <u>Threat Groups</u>

Groups that might attempt sabotage, theft or diversion can be classified as subnational and national (or multinational) as discussed below.

A.3.1 <u>Subnational</u>

Subnational originators can be 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 the means.[1] Individuals, dissident employees, extremists, and other domestic groups may select nuclear targets, but none has yet demonstrated the ability to do

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 indentifiable characteristics	Average	High	Average to high	Average
Foreign Revolutionaries	Political changes	Local political institutions	Average	High	Average to high	Average

a. N. R. Wagner Reference 1.

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 C threat. They are unlikely to attack a nuclear facility, an extremely provocative act, unless their relationship with the nation housing the nuclear facility deteriorates.

10-b A.3.2 National (or Multinational)

A national (or multinational) threat considered as safeguards is a decision by a non-nuclear weapons state to acquire a nuclear explosive device by diverting and chemically processing nuclear materials intended for peaceful nuclear activities. Such a decision would depend upon a number of complex political, diplomatic, and military considerations. In the final analysis, a country's perception of its national security needs will probably be the most important factor in any decision to develop nuclear explosives.[2]

The spread of nuclear weapons would significantly magnify the threat of nuclear war, increase global political instability, adversely affect U.S. foreign relations, and have a negative and costly impact on our national defense. Historically, the U.S. has worked to discourage proliferation, through its cooperative agreements, the creation of the IAEA safeguards system, its alliance system and security guarantees, the NPT, and through consultations with other supplying nations.[2]

C B. Safeguard Controls Against Sabotage and Theft

B.1 General Domestic and Foreign Controls

B.1.1 Domestic Controls

The physical protection requirements at U.S. storage facilities for foreign spent fuel and during transportation of foreign spent fuel in the U.S. are the same as for domestic fuel and are specified in NRC regulations (10 CFR 73)[3], as discussed in Volume 2. Measures required for the purpose of protection against acts of sabotage or theft include (1) protective barriers and intrusion detection devices, (2) deterrence to attack by means of armed guards and escorts, and (3) liaison and communication with law enforcement authorities capable of rendering assistance to counter such attacks.

As summarized in Reference 2, it is quite clear that a precise quantitative evaluation of the effectiveness of the domestic safeguards system as a whole is not possible at this time. However, DOE and its predecessors have employed professionals in the areas of physical protection, materials accountancy, measurement technology, chemistry, nuclear materials processing, statistical techniques, and other related safeguards disciplines to ensure that the best experienced judgment is brought to bear on the problems related to theft and diversion. Also, knowledgeable contractors and consultants have been used in this area. Over the years, many external in-depth studies of the safeguards system have been undertaken, and the conclusions and recommendations of these studies have been considered. It is recognized by all of the professionals involved that the system could never assure complete protection. There can be component failures (e.g., malfunction of electronic component in alarm systems), "weak links" in the system, or the threat that the system it is designed to counter may change. It is precisely for these reasons that the current system designs call for "in-depth" measures and that procedures and devices continue to be developed to provide greater protection.

C

B.1.2 IAEA Controls

As indicated in Volume 2, ISFS facilities that receive foreign fuel are assumed to meet NRC licensing requirements that implement a US/IAEA safeguards agreement.[4] Foreign transportation will also meet the IAEA safeguards arrangements that are negotiated between the IAEA and involved countries. The overall purpose of these agreements is to provide a credible assurance that states do not divert special nuclear material from peaceful to military purposes. The specific objectives of IAEA guidelines used in negotiating safeguard agreements are 1) the timely detection of diversion of significant quantities of nuclear materials from peaceful nuclear activities, and 2) the deterrence of such diversion by risk of early detection and by sanctions, including the political consequences of reporting diversions to the international community.

Nuclear material accountancy is the fundamental IAEA safeguard tool, while containment and surveillance serve as important complementary measures.

It is not technically possible to demonstrate quantitatively whether, or to what degree, present international safeguards actually accomplish their desired effects. However, the fact that no nation has entered the nuclear club by using nuclear material subject to IAEA safeguards is surely, in some degree at least, related to the existence and effectiveness of those safeguards. The risks of detection under IAEA safeguards are substantial. As the May 1975 Presidential Report to Congress[5] concluded, "Based upon our experience with IAEA accountancy safeguards, it is our judgment that the system will detect and thus make an important contribution to deterring any efforts at diversion by states."

Nevertheless, as the volume of material increases and as the facilities elsewhere in the world grow in their technical complexities, requirements to maintain a high level of safeguards will include improvements in safeguards equipment and increases in staffing, frequency of inspection, and funding of the IAEA system. A high level of U.S. financial, diplomatic, and technical assistance will be needed to support this effort, since U.S. involvement and support of the IAEA is essential, if the U.S. is to continue to have a positive influence on the safeguards policies and programs of the agency.

The U.S. has been a leader in working toward the adoption of adequate international physical security measures. The U.S. took the lead in supporting the IAEA's major effort in April 1975 to review and update recommendations[2] developed under the agency's auspices (published in March 1972) for the physical security of nuclear materials. The U.S. is encouraging the adoption of effective physical security measures in other countries by its support of an international convention on physical security and by its own physical security development efforts. Further, the U.S. Nuclear Regulatory Commission has recently submitted to the U.S. Senate a proposed formal agreement between the U.S. Government and IAEA for applying IAEA safeguards in the U.S.[4] The U.S. maintains an active research and development program to develop up-to-date techniques and equipment designed to cope with all types of possible threats. The U.S. is exchanging technical information in this area with the IAEA and on a bilateral basis with other nations. The Spent Fuel Storage Policy is but one of many means of improving international physical security.

B.1.3 Other Controls

Other activities by the U.S. include NASAP, INFCE, the DOE converter fuel cycle programs, and EPA and NRC programs. These programs are discussed in Section II. The details of the nonproliferation advantages for the various levels of implementation of the Spent Fuel Storage Policy are described in Sections II and III. The nonproliferation considerations that may exist if the policy is not implemented are described in Case A. In Cases B through H, alternative means of meeting the U.S. nonproliferation goals are described as they relate to the foreign spent fuel.

B.2 Controls for Specific Nuclear Facilities

B.2.1 Sabotage of Nuclear Facilities

Volume 2 of this final EIS discusses sabotage during transportation of spent fuel in the U.S. and during handling and storage in water basin facilities in the U.S. This section describes the consequences of sabotage of foreign spent fuel during transport (not included in Volume 2), during reprocessing and refabrication at the FRP-MOX plants, and during disposal at the geologic repositories.

One aim of the Spent Fuel Storage Policy is to limit U.S. licensed and foreign facilities that handle sensitive materials and if reprocessing facilities for spent fuel do exist, to ensure that adequate safeguard controls and designs are built into these facilities to ensure protection of nuclear materials.

B.2.1.1 Transportation Sabotage

The sabotage of the ships used for transport of foreign fuel to the U.S. for storage is an additional transportation concern not included in Volume 2. Large shipping casks, similar to those discussed in Volume 2, will be used for the maritime transport. If a ship transporting spent fuel were sabotaged and sunk, the cask would probably be recoverable. Equipment for deep-sea recovery of ships and cask-size objects has been developed and used.[6] Sunken ships have been recovered from depths greater than 5 km (3 mi) and cask-shaped objects have been recovered from steep and unstable walls of marine canyons.[7] Other items have been located and recovered from depths exceeding 6 km (4 mi) or about twice the mean ocean depth.[8]

10-c The diversion or piracy of a ship carrying spent fuel presents a low risk since the felonious act would be detected within one day and action would be taken to recover the ship.[2] Cargo ships of the type assumed in this volume maintain ship-to-shore radio contact and report their positions at least daily. If communications from the ships are not received as prearranged, search and recovery operations would be initiated by the shipper's agent through national and international agencies.[2] These prearranged search and recovery operations will be included in agreements between the involved countries based on IAEA guidelines and procedures relative to spent fuel safeguards.

10-a In Volume 2 of this final EIS, it is concluded that the possibility of sabotage of spent fuel casks that results in large releases of radioactive materials are unlikely during U.S. land transportation. NRC has recently modified regulations pertaining

10-a to physical protection of spent fuel during transportation (route approved by NRC and required escort surveillance and emergency response training) with the intent of ensuring that adequate safety and environmental protection are provided to prevent or mitigate sabotage conditions. These rules, together with considerations that normal routing of shipments usually avoids areas of high-population density and that the obstacles attackers must overcome to disperse contents from a spent fuel or a reprocessing waste cask are formidable, lead to the conclusion that the risk to the public associated with potential sabotage acts is low.

B.2.1.2 Storage Basin Sabotage

As indicated in Volume 2, penetration of storage basin facilities by a casual or spontaneous attempt is very unlikely. Penetration might be accomplished by a thoroughly planned and well-armed attack group. A number of potential sabotage acts were postulated that would meet these conditions. Analyses of these sabotage scenarios in Volume 2 of this final EIS showed that an individual on the plant boundary would receive a dose of less than three rem, which would not endanger his or her health.

B.2.1.3 Geologic Repository Sabotage

At the geologic repository, encapsulation and surface handling of spent fuel or reprocessing waste will be carried out behind shielding equivalent to at least several feet of concrete to protect operating personnel. The operations will be conducted in facilities with ventilation control, and the buildings will be constructed to withstand design-basis tornadoes and earthquakes as specified in Regulatory Guides 1.76[9] and 3.24.[10] In addition, security personnel and protection systems similar to those described for storage basins in Volume 2 will be available. Under these conditions, the fuel elements will be inaccessible to saboteurs without great effort; thus, sabotage of the geologic repository facility, while surface operations are underway, is not considered to represent a safeguards-related hazard to the public.

Emplacement of fuel in the geologic repository is expected to take place a thousand feet or more underground in a salt mine. Even during the time the spent fuel or reprocessing waste is considered retrievable, access to fuel at this location will require sophisticated and remotely controlled equipment. After the repository is sealed, access will be even more difficult. The acquisition, emplacement, and operation of such equipment by any threat group is considered to be incredible.

B.2.1.4 Spent Fuel Reprocessing and Fuel Fabrication Plant Sabotage

Regulatory requirements for the design and operation of a reprocessing fuel fabrication plant provide a very high degree of protection against forced entry and sabotage. However, sabotage attempts are considered credible. Sabotage attempts include the attempted use of chemical explosives or other devices to cause physical damage to key safety systems or equipment, either inside or outside facility buildings, and the attempted use of flammable or pyrophoric materials to initiate fires inside the facilities.

A successful effort that resulted in a general facility fire
C in a mixed oxide fabrication plant would release about 0.01 g of plutonium oxide to the environment. As the result of this release an individual near the plant would receive a dose of about 0.2 rem[11] (bone). This hypothetical event represents the upper range of consequences from sabotage of a reprocessing fuel fabrication plant.

C

B.2.2 Theft from Nuclear Facilities

As discussed in the section on sabotage of nuclear facilities, one aim of the Spent Fuel Storage Policy is to ensure that adequate safeguards controls and design are built into domestic and foreign facilities to ensure protection of nuclear materials. These safeguard controls include protection against theft of nuclear materials.

This section discusses theft from nuclear facilities by force or by diversion and also theft during transportation operations. Theft from nuclear facilities by force requires that the group overcome and elude law enforcement authorities responding to a request for assistance in addition to overcoming formidable obstacles discussed in the preceding section on sabotage of nuclear facilities. Therefore, successful theft and accomplishment of subsequent malevolent acts appears unlikely.

B.2.2.1 Theft from Storage or Reprocessing Facilities

Buildings for fuel storage, geologic storage, or reprocessing operations will be constructed to meet the safeguards requirements outlined in 10 CFR 73.[3] 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.

C 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 group. At the first signs of an attack, the control room operator would alert local law enforcement agencies and help would start arriving within 15 minutes.

The theft group must overcome the guard force protecting the facility to make entry to the location of the materials. In the unlikely event that the theft group successfully steals a shipping cask containing the material from a facility, there is no radiological hazard. To cause any radiological or environmental concerns, the theft force must elude law enforcement authorities until the shipping cask is sabotaged. Alternatively, the theft group might attempt to use the stolen material to blackmail a local government by threatening to sabotage or disperse the radioactive material. If the shipping cask were successfully sabotaged, the potential radiological and economic impacts might be on the scale of a severe transportation accident resulting in the breaching of a spent fuel cask.

The theft of materials from a storage or reprocessing facility (or during transportation) for purposes of procuring fissionable material for an improvised nuclear device requires eluding of law enforcement authorities for several weeks. Another form of theft of nuclear material for the purpose of an improved nuclear device could be the illicit removal of small amounts of intermediate products from the FRP-MOX facilities. Safeguard controls and procedures in FRP-MOX are designed to prohibit such thefts. Personnel monitoring, work crew audits, stringent inventory control and audits and other measures are required by NRC regulations.

B.2.2.2 Theft During Transportation

NRC safeguard regulations (10 CFR 73[3]) for protection of spent and recycled fuel during transportation require shipping route approval by NRC, vehicle disabling devices, escort surveillance, continuous communications, emergency response training and prearranged liaison with law enforcement authorities along the route. Theft of nuclear materials during transportation would require overcoming these protective measures. In the unlikely event of a successful theft, there would be no immediate radiological concern.

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10. U.S. Nuclear Regulatory Guide 3.24: Guidance on the License Application, Siting, Design and Plant Protection for an Independent Spent Fuel Storage Installation. U.S. Nuclear Regulatory Commission, Washington, DC (December 1974).

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V. UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

A. Nonproliferation

As part of the Spent Fuel Policy, the U.S. would accept limited quantities of foreign spent fuel when this action would "contribute to meeting nonproliferation goals." This policy was designed to demonstrate feasibility of alternatives to premature reprocessing of spent fuel and the recycling of plutonium. These actions by the U.S. are intended to encourage other nations in similar international efforts. This combination of efforts would help nations to exercise restraint in moving toward a plutonium economy and to provide time to pursue the development of more proliferation-resistant fuel cycle technologies.

The U.S. policy also supports restricting the location of sensitive materials and sensitive activities, such as reprocessing, to as few locations as possible. The policy also encourages any such facilities to use appropriate institutional arrangements, international safeguards, and proliferation-resistant technologies that meet the requirements of the U.S. nonproliferation policy. Technologies and institutional arrangements that reduce the risk of diversion of refabricated fuel produced in a secured facility are also required. Reprocessing and recycling in any form still represent more of a proliferation risk than interim storage and disposal of spent fuel.

C To the extent that these goals are not achieved, either by nonimplementation or because only a fraction of the spent fuel is covered, there will be an unavoidable proliferation risk. Some of those nations lacking sufficient internal storage capability may turn to reprocessing as an alternative. These nations will acquire sensitive facilities capable of producing material usable in nuclear weapons.

Estimates of the nonproliferation implications of the U.S. offer to accept foreign fuel, however, are judgmental and speculative at this time. These implications will depend upon how foreign nations choose to dispose of their spent fuel. Such decisions will be based upon costs and availability of alternatives, including the U.S. storage offer, national fuel cycle plans, expanded national storage, and nonproliferation considerations.

B. Radiological

Radiation doses to the general population from the transportation, storage, reprocessing, or disposal of foreign fuel 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. Calculated health effects from cases considered assuming initial U.S. geologic repository operation begins by the year 1995 are discussed in Section III. Health effects to the U.S. and global commons are summarized in Table V-1 and those to the world are summarized C in Table V-2 for those cases analyzed in Section III. Effects from Cases I and J (see Appendix A) are not included in this section. They are however comparable to the health effects given in Tables V-1 and V-2. The health effects for cases with reprocessing include only the back-end effects (storage, reprocessing, and refabrication of the plutonium and uranium for reuse) of the fuel cycle. If fuel is reprocessed and plutonium and uranium are recycled, virgin uranium feed requirements will be decreased and will result in a reduction in mining and milling operations. This reduction of mining and milling at the front end of the fuel cycle will result in a decrease of 120 health effects from population dose commitment and occupational exposure as discussed C in Section III. These reduced mining and milling effects more than affect the health effects arising from transportation storage, reprocessing or ultimate disposition of the foreign spent fuel analyzed in this report. However, in this environmental tradeoff analysis, mining and milling environmental effects are not included because they are not directly associated with the operations at the back end of the fuel cycle that are directly affected by the Spent Fuel Policy.

A comparison of total radiological health effects for different foreign spent fuel schedules (for both a 1985 and a 1995 startup of the geologic repository) are shown in Table V-3. The number of potential health effects for a 1995 repository startup date is higher, in all cases, than for a 1985 disposition date; these increases are due primarily to the longer period of operation of ISFS facilities and a larger amount of spent fuel in storage.

C. Potential Accidents

The potential adverse effects on the offsite population from radiological releases following possible accidents (discussed in Section III C) are well within the limits given in 10 CFR 100[1] and DOE Manual Chapter 6301.[2]

A summary of the expected accidental deaths caused by non-radiological occupational accidents for the back-end of the fuel cycle is given in Table V-4. The number of occupational deaths 7-j ranges from 0.56 to 4.2 for those cases not involving spent fuel reprocessing (Cases D, G, and H) and 7.9 to 10.9 for those including reprocessing. The decrease in the number of deaths from decreased mining and milling of uranium because of recycle of recovered uranium and plutonium would be 31.

TABLE V-1

Radiological Health Effects to the U.S. and Global Commons — All Cases[a]

Case Description		Health Effects from Population Dose Commitment and Occupational Exposure[b] — 1985 Geologic Startup: Interim Operations	1985 Geologic Startup: Disposition Activities	1985 Geologic Startup: Total	1995 Geologic Startup: Interim Operations	1995 Geologic Startup: Disposition Activities	1995 Geologic Startup: Total
Fuel Remains in Foreign Countries (Option 3 Fuel Schedule)	A,B&C[c]	0	3.2	3.2	*d*	*d*	*d*
Fuel Shipped to U.S. for Storage — Later Disposed of in U.S. Geologic Repository (Option 3 Fuel Schedule)	D	0.74	0.28	1.02	2.54	0.27	2.81
Fuel Shipped to U.S. — Later Returned for Reprocessing (Option 3 Fuel Schedule)	E	0.83	3.5	4.3	*d*	*d*	*d*
Fuel Shipped to U.S. — Later Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule)	F-1	0.96	10.1	11.1	*d*	*d*	*d*
Fuel Shipped to U.S. — Later Reprocessed in U.S. Pu and U Returned (Option 3 Fuel Schedule)	F-2	0.96	10.3	11.3	*d*	*d*	*d*
Fuel Shipped to U.S. for Storage — Later Disposed of in U.S. Geologic Repository (Option 2 Fuel Schedule)	G	0.19	0.09	0.28	0.93	0.09	1.02
Fuel Shipped to U.S. for Storage — Later Disposed of in U.S. Geologic Repository (Option 1 Fuel Schedule)	H	0.08	0.04	0.12	0.46	0.05	0.51

a. Back-end of fuel cycle does not include mining and milling effects.

b. Total cancers and serious genetic effects calculated from radiation doses, assuming a linear dose-health effect relation. EPA dose-effect factors[3,4] were used. Health effects from organ doses are not shown independently, but these organ health effects are included under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. In Cases B and C, reprocessing is deferred; and effects are about the same as Case A but are delayed.

d. Case not analyzed.

TABLE V-2

Radiological Health Effects to the World — All Cases[a]

Case Description		Health Effects from Population Dose Commitment and Occupational Dose[b]: 1985 Geologic Repository Startup — Interim Operations	1985 Geologic Repository Startup — Disposition Activities	1985 Geologic Repository Startup — Total	1995 Geologic Repository Startup — Interim Operations	1995 Geologic Repository Startup — Disposition Activities	1995 Geologic Repository Startup — Total
Fuel Remains in Foreign Countries (Option 3 Fuel Schedule)	A,B,& C[c]	0.01	10.5	10.5	*d*	*d*	*d*
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 3 Fuel Schedule)	D	0.78	0.28	1.06	2.57	0.27	2.84
Fuel Shipped to U.S. - Later Returned for Reprocessing (Option 3 Fuel Schedule)	E	0.85	9.8	10.6	*d*	*d*	*d*
Fuel Shipped to U.S. - Later Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule)	F-1	1.0	10.1	11.1	*d*	*d*	*d*
Fuel Shipped to U.S. - Later Reprocessed in U.S. - Plutonium and Uranium Returned (Option 3 Fuel Schedule)	F-2	1.0	10.4	11.4	*d*	*d*	*d*
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 2 Fuel Schedule)	G	0.21	0.09	0.30	0.94	0.09	1.03
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 1 Fuel Schedule)	H	0.08	0.05	0.13	0.47	0.05	0.52

a. Back-end of fuel cycle does not include mining and milling effects.

C *b.* Total cancers and serious genetic effects calculated from radiation dose, assuming a linear dose-health effect relation. EPA dose-effect factors[3,4] were used. Health effects from organ doses are not shown independently, but these organ health effects are included under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. In Cases B and C, reprocessing is deferred; and effects are about the same as Case A but are delayed.

d. Case not analyzed.

TABLE V-3

Effects of Foreign Fuel Schedules and Geologic Startup

Description	*World Radiological Health Effects - Total*[a] *1985 Geologic Repository Startup*	*1995 Geologic Repository Startup*
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository		
Option 1 Fuel Schedule	0.13	0.52
Option 2 Fuel Schedule	0.30	1.03
Option 3 Fuel Schedule	1.06	2.84

C *a.* Total cancers and serious genetic effects calculated from radiation dose, assuming a linear dose-health effect relation. EPA dose-effect factors[3,4] were used. Health effects from organ doses are not shown independently, but these organ health effects are included under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

TABLE V-4

Occupational Deaths from Accidents -- Back-end of Fuel Cycle

		Deaths — World Total					
		1985 Geologic Repository Startup			*1995 Geologic Repository Startup*		
Case Description		*Interim Operations*	*Disposition Activities*	*Total*	*Interim Operations*	*Disposition Activities*	*Total*
7-j Fuel Remains in Foreign Countries (Option 3 Fuel Schedule)	A,B&C[a]	0.4	7.5	7.9	*b*	*b*	*b*
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 3 Fuel Schedule)	D	1.6	1.8	3.4	2.4	1.8	4.2
Fuel Shipped to U.S. - Later Returned for Reprocessing (Option 3 Fuel Schedule)	E	1.2	7.1	8.3	*b*	*b*	*b*
Fuel Shipped to U.S. - Later Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule)	F-1	1.8	7.6	9.4	*b*	*b*	*b*
Fuel Shipped to U.S. - Later Reprocessed in U.S. - Plutonium and Uranium Returned (Option 3 Fuel Schedule)	F-2	1.8	9.1	10.9	*b*	*b*	*b*
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 2 Fuel Schedule)	G	0.47	0.66	1.1	0.82	0.66	1.5
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 1 Fuel Schedule)	H	0.22	0.34	0.56	0.38	0.34	0.72

a. In Case A, no operations occur in the U.S. or the global commons. For Cases B and C, there are no operations with foreign spent fuel in the U.S., but some fuel may be shipped by sea between countries other than the U.S.

b. Case not analyzed.

TABLE V-5

Permanent Land Commitments for Foreign Fuel Increments

Case Description		*Land Commitments, acres*[a] — *1985 Geologic Repository Startup* — *U.S. and Global Commons*	*World*	*1995 Geologic Repository Startup* — *U.S. and Global Commons*	*World*
Fuel Remains in Foreign Countries (Option 3 Fuel Schedule)	A,B&C	0	28	*b*	*b*
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 3 Fuel Schedule)	D	27	27	27	27
Fuel Shipped to U.S. - Later Returned for Reprocessing (Option 3 Fuel Schedule)	E	0	28	*b*	*b*
Fuel Shipped to U.S. - Later Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule)	F-1	28	28	*b*	*b*
Fuel Shipped to U.S. - Later Reprocessed in U.S. - Plutonium and Uranium Returned (Option 3 Fuel Schedule)	F-2	28	28	*b*	*b*
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 2 Fuel Schedule)	G	9.1	9.1	9.1	9.1
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 1 Fuel Schedule)	H	4.4	4.4	4.4	4.4

a. Surface land used for salt tailings from geologic repositories.

b. Case not analyzed.

D. Other

Permanent land commitment resulting from the foreign spent fuel for all facilities is listed for individual cases in Section VI and is summarized in Table V-5. The only permanent commitment of surface land resources will be 1.8 to 11 hectares (4.4 to 28 acres) used for disposal of salt tailings from geologic repositories. Approximately 18 to 110 hectares (44 to 280 acres) of subsurface land will be permanently committed by geologic repositories for storage of foreign spent fuel. Land used by all other facilities will be returned to other unrestricted or productive uses after decontamination and decommissioning.

Other unavoidable adverse environmental effects are water and energy requirements and chemical discharges. Water and energy requirements are discussed in Section VI and are not large in terms of available resources or environmental impact. Chemical discharges are discussed in References 5 and Volume 2 and are also small.

REFERENCES FOR SECTION V

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

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

3. Environmental Analysis of the Uranium Fuel Cycle. Report EPA-520/9-73-0038, U.S. Environmental Protection Agency, Washington, DC (1973).

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

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

VI. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Resources that are committed in an irreversible and irretrievable manner by the cases considered in this volume consist of

- Land areas permanently affected
- Manpower for construction, operation, and decommissioning of storage facilities, reprocessing plants, and transportation equipment
- Materials such as fuels and chemicals consumed and construction materials that are not recyclable.

The resource commitments presented in this section are the increments associated with storage of foreign spent fuel for cases discussed in Section III of this volume. Resource commitments were not analyzed for Cases I and J (Appendix A) but those commitments are comparable to those presented in this section.

For the various cases, principal resource commitments in the U.S. and global commons are shown in Tables VI-1 and VI-2 and for the world, in Tables VI-3 and VI-4. The transportation systems are presumed to exist, except for truck casks and rail casks which have been included in the estimates.

Land committed permanently at geologic repositories by the foreign fuel increment in the U.S. and global commons and in the world is shown in Tables VI-1 and VI-3. In the context of this volume, such committed land will have restricted use either permanently or for at least several hundred years.

In the dismantlement mode of decommissioning selected for ISFS installations (Appendix B of Volume 2) and fuel reprocessing-fabrication plants, there is no permanent commitment of land. Land occupied by the burial grounds - the disposal areas for low-level radioactive waste — will be restricted for several hundred years; however, when the fission and activation products in the burial ground trenches decay to innocuous levels, the land may be returned to productive use.

As can be seen from Tables VI-1 and VI-3, there is permanent commitment of both near-surface and underground land at geologic repositories.[1] The land area above a geologic repository will require permanent restrictions to ensure a three-dimensional safety zone around the repository. All subsurface activities will be prohibited, but surface land activities that do not imperil the integrity of the repository will be unrestricted. In this EIS, mined salt is assumed to be permanently stored at the site[1] to conservatively estimate the adverse environmental effects projected in the analysis. However, as explained in Reference 1, the salt tailings may be removed for commercial use or disposal elsewhere. The permanent land commitment shown in Tables VI-1

TABLE VI-1

Permanent Land Commitment in U.S. and Global Commons from the Foreign Fuel Increment, Acres[a]

	Case A, B or C — *Fuel Remains in Foreign Countries (Option 3 Fuel Schedule)*	*Case D* — *Fuel Shipped to U.S. - Later Disposed of in a Geologic Repository (Option 3 Fuel Schedule)*		*Case E* — *Fuel Shipped to U.S. and Reprocessed - Later Returned (Option 3 Fuel Schedule)*
	1985 Geologic Repository Startup	*1985 Geologic Repository Startup*	*1995 Geologic Repository Startup*	*1985 Geologic Repository Startup*
At Geologic Repositories:				
Surface[b]	None	27	27	None
Subsurface[c]	None	270	270	None

	Case F-1 — *Fuel Shipped to U.S. - Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule)*	*Case F-2* — *Fuel Shipped to U.S.- Reprocessed in U.S. - Pu and U Returned (Option 3 Fuel Schedule)*	*Case G* — *Fuel Shipped to U.S. - Later Disposed of in a Geologic Repository (Option 2 Fuel Schedule)*	
	1985 Geologic Repository Startup	*1985 Geologic Repository Startup*	*1985 Geologic Repository Startup*	*1995 Geologic Repository Startup*
At Geologic Repositories:				
Surface[b]	28	28	9.1	9.1
Subsurface[c]	280	280	91.0	91.0

	Case H — *Fuel Shipped to U.S. - Later Disposed of in a Geologic Repository (Option 1 Fuel Schedule)*	
	1985 Geologic Repository Startup	*1995 Geologic Repository Startup*
At Geologic Repositories:		
Surface[b]	4.4	4.4
Subsurface[c]	44.0	44.0

a. Following decommissioning of facilities and burial grounds, the only land permanently committed is that utilized at geologic repositories for entombment of foreign spent fuel under consideration, and/or associated wastes.

b. Salt tailings from the geologic repository, if not removed from sites (Reference 1).

c. Activities on land above this subsurface area have restrictions to ensure integrity of the geologic repositories (Reference 1).

TABLE VI-2

Resource Commitments in U.S. and Global Commons from the Foreign Fuel Increment, Other than Land

Resource	*Case A, B or C* *Fuel Remains in Foreign Countries (Option 3 Fuel Schedule)* *1985 Geologic Repository Startup*			*Case D* *Fuel Shipped to U.S. - Later Disposed of in a Geologic Repository (Option 3 Fuel Schedule)* *1985 Geologic Repository Startup*			*Case D* *1995 Geologic Repository Startup*			*Case E* *Fuel Shipped to U.S. - Later Returned and Reprocessed (Option 3 Fuel Schedule)* *1985 Geologic Repository Startup*		
	Interim	*Disposition*	*Total*	*Interim*	*Disposition*	*Total*	*Interim*	*Disposition*	*Total*	*Interim*	*Disposition*	*Total*
Water, m^3	0	0	0	1.8×10^{6}	1.0×10^{5}	1.9×10^{6}	1.2×10^{7}	1.5×10^{5}	1.2×10^{7}	3.1×10^{6}	3.1×10^{4}	3.1×10^{6}
Materials:												
Concrete, m^3	0	0	0	8.0×10^{3}	1.0×10^{4}	1.8×10^{4}	2.3×10^{4}	1.3×10^{4}	3.6×10^{4}	8.7×10^{4}	4.7×10^{3}	9.2×10^{4}
Steel, tonne	0	0	0	5.0×10^{3}	2.0×10^{4}	2.5×10^{4}	1.5×10^{4}	2.9×10^{4}	4.4×10^{4}	1.2×10^{5}	8.3×10^{3}	1.3×10^{5}
Copper,[a] tonne	0	0	0	1.1×10^{1}	2.1×10^{1}	3.2×10^{1}	3.1×10^{1}	2.1×10^{1}	5.1×10^{1}	1.5×10^{2}	8.2×10^{0}	1.6×10^{2}
Zinc,[a] tonne	0	0	0	1.9×10^{1}	5.1×10^{0}	2.4×10^{1}	5.2×10^{1}	5.1×10^{0}	5.7×10^{1}	5.4×10^{1}	2.0×10^{0}	5.6×10^{1}
Aluminum,[a] tonne	0	0	0	0	3.8×10^{0}	3.8×10^{0}	0	3.8×10^{0}	3.8×10^{0}	2.6×10^{1}	1.5×10^{0}	2.7×10^{1}
Lumber, m^3	0	0	0	4.7×10^{2}	3.0×10^{2}	7.7×10^{7}	1.3×10^{3}	3.0×10^{7}	1.6×10^{3}	2.5×10^{3}	1.2×10^{2}	2.6×10^{3}
Lead,[a] tonne	0	0	0	0	0	0	0	0	0	0	0	0
Depleted uranium,[a] tonne	0	0	0	0	0	0	0	0	0	0	0	0
Chromium[a] in S.S.,[b] tonne	0	0	0	3.1×10^{2}	0	3.1×10^{2}	1.2×10^{3}	0	1.2×10^{3}	3.1×10^{2}	0	3.1×10^{2}
Nickel[a] in S.S.,[b] tonne	0	0	0	1.4×10^{2}	0	1.4×10^{2}	5.2×10^{7}	0	5.2×10^{7}	1.4×10^{7}	0	1.4×10^{7}
E Uranium,[c] tonne	0	0	0	0	1.3×10^{4}	1.3×10^{4}	0	1.3×10^{4}	1.3×10^{4}	0	0	0
Plutonium,[c] tonne	0	0	0	0	8.3×10^{1}	8.3×10^{1}	0	8.3×10^{1}	8.3×10^{1}	0	0	0
Zirconium,[c] tonne	0	0	0	0	2.6×10^{3}	2.6×10^{3}	0	2.6×10^{3}	2.6×10^{3}	0	0	0
Energy:												
Propane, m^3	0	0	0	2.1×10^{2}	1.3×10^{2}	3.3×10^{2}	5.7×10^{7}	1.3×10^{7}	7.0×10^{7}	2.9×10^{3}	5.0×10^{1}	3.0×10^{3}
Diesel fuel, m^3	0	0	0	2.5×10^{5}	1.7×10^{4}	2.7×10^{5}	2.2×10^{5}	1.6×10^{4}	2.4×10^{5}	2.0×10^{5}	6.1×10^{3}	2.1×10^{5}
Gasoline, m^3	0	0	0	3.7×10^{3}	9.3×10^{7}	4.6×10^{3}	9.9×10^{3}	9.3×10^{2}	1.1×10^{4}	9.4×10^{3}	3.8×10^{2}	9.8×10^{3}
Electricity, kWh	0	0	0	2.6×10^{8}	5.2×10^{8}	7.8×10^{8}	1.7×10^{9}	5.2×10^{8}	2.2×10^{9}	6.7×10^{9}	4.2×10^{8}	7.1×10^{9}
Coal,[d] tonne	0	0	0	1.6×10^{5}	1.7×10^{5}	3.4×10^{5}	1.2×10^{6}	1.7×10^{5}	1.3×10^{6}	1.3×10^{6}	1.4×10^{5}	1.5×10^{6}
Manpower, man-hour	0	0	0	5.6×10^{6}	5.4×10^{6}	1.1×10^{7}	1.3×10^{7}	5.5×10^{6}	1.8×10^{7}	3.9×10^{7}	2.0×10^{6}	4.1×10^{7}

a. A large portion of these construction materials may be recyclable, if desired.

b. In stainless steel.

c. In buried spent fuel or reprocessing waste.

d. Total coal for generation of process steam and building heat and generation of electrical energy at coal-fired utilities.

TABLE VI-2 (Continued)

Resource Commitments in U.S. and Global Commons from the Foreign Fuel Increment, Other than Land

Resource	*Case F-1* Fuel Shipped to U.S. - Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule) 1985 Geologic Repository Startup			*Case F-2* Fuel Shipped to U.S. - Reprocessed in U.S. - Pu and U Returned (Option 3 Fuel Schedule) 1985 Geologic Repository Startup		
	Interim	*Disposition*	*Total*	*Interim*	*Disposition*	*Total*
Water, m^3	3.0×10^6	5.3×10^6	8.3×10^6	3.0×10^6	5.3×10^6	8.3×10^6
Materials:						
Concrete, m^3	8.2×10^4	1.2×10^5	2.0×10^5	8.2×10^4	1.2×10^5	2.0×10^5
Steel, tonne	1.2×10^5	7.6×10^4	1.9×10^5	1.2×10^5	7.6×10^4	1.9×10^5
Copper,[a] tonne	1.4×10^2	1.2×10^2	2.6×10^2	1.4×10^2	1.2×10^2	2.6×10^2
Zinc,[a] tonne	5.0×10^1	1.9×10^1	6.9×10^1	5.0×10^1	1.9×10^1	6.9×10^1
Aluminum,[a] tonne	2.3×10^1	5.4×10^1	7.8×10^1	2.3×10^1	5.4×10^1	7.8×10^1
Lumber, m^3	2.3×10^3	2.5×10^3	4.8×10^3	2.3×10^3	2.5×10^3	4.8×10^3
Lead,[a] tonne	0	1.7×10^3	1.7×10^3	0	1.7×10^3	1.7×10^3
Depleted uranium,[a] tonne	0	0	0	0	0	0
Chromium[a] in S.S.,[b] tonne	3.1×10^2	1.0×10^2	4.1×10^2	3.1×10^2	1.0×10^2	4.1×10^2
Nickel[a] in S.S.,[b] tonne	1.4×10^2	4.6×10^1	1.8×10^2	1.4×10^2	4.6×10^1	1.8×10^2
Uranium,[c] tonne	0	2.6×10^1	2.6×10^1	0	2.6×10^1	2.6×10^1
Plutonium,[c] tonne	0	1.7×10^{-1}	1.7×10^{-1}	0	1.7×10^{-1}	1.7×10^{-1}
Zirconium,[c] tonne	0	2.6×10^3	2.6×10^3	0	2.6×10^3	2.6×10^3
Energy:						
Propane, m^3	9.7×10^2	5.1×10^3	6.1×10^3	9.7×10^2	5.1×10^3	6.1×10^3
Diesel fuel, m^3	3.0×10^5	5.2×10^5	8.2×10^5	4.9×10^5	5.2×10^5	1.0×10^6
Gasoline, m^3	9.1×10^3	6.0×10^3	1.5×10^4	9.1×10^3	6.0×10^3	1.5×10^4
Electricity, kWh	6.6×10^9	5.7×10^9	1.2×10^{10}	6.6×10^9	5.7×10^9	1.2×10^{10}
Coal,[d] tonne	1.4×10^6	3.6×10^6	5.0×10^6	1.4×10^6	3.6×10^6	5.0×10^6
Manpower, man-hour	3.7×10^7	6.9×10^7	1.1×10^8	3.9×10^7	6.9×10^7	1.1×10^8

Resource	*Case G* Fuel Shipped to U.S. - Later Disposed of in a Geologic Repository (Option 2 Fuel Schedule) 1985 Geologic Repository Startup			1995 Geologic Repository Startup		
	Interim	*Disposition*	*Total*	*Interim*	*Disposition*	*Total*
Water, m^3	6.7×10^5	3.6×10^4	7.1×10^5	4.9×10^6	5.5×10^4	4.9×10^6
Materials:						
Concrete, m^3	2.8×10^3	3.7×10^3	6.5×10^3	8.8×10^3	4.6×10^3	1.3×10^4
Steel, tonne	1.8×10^3	6.5×10^3	8.3×10^3	6.0×10^3	9.7×10^3	1.6×10^4
Copper,[a] tonne	3.9×10^0	7.4×10^0	1.1×10^1	1.2×10^1	7.4×10^0	1.9×10^1
Zinc,[a] tonne	6.7×10^0	1.8×10^0	8.6×10^0	2.0×10^1	1.8×10^0	2.2×10^1
Aluminum,[a] tonne	0	1.4×10^0	1.4×10^0	0	1.4×10^0	1.4×10^0
Lumber, m^3	1.7×10^2	1.1×10^2	2.7×10^2	4.8×10^2	1.1×10^2	5.9×10^2
Lead,[a] tonne	0	0	0	0	0	0
Depleted uranium,[a] tonne	0	0	0	0	0	0
Chromium[a] in S.S.,[b] tonne	1.1×10^2	0	1.1×10^2	4.5×10^2	0	4.5×10^2
Nickel[a] in S.S.,[b] tonne	4.8×10^1	0	4.8×10^1	2.0×10^2	0	2.0×10^2
Uranium,[c] tonne	0	4.2×10^3	4.2×10^3	0	4.2×10^3	4.2×10^3
Plutonium,[c] tonne	0	2.7×10^1	2.7×10^1	0	2.7×10^1	2.7×10^1
Zirconium,[c] tonne	0	8.4×10^2	8.4×10^2	0	8.4×10^2	8.4×10^2
Energy:						
Propane, m^3	7.4×10^1	4.6×10^1	1.2×10^2	2.2×10^2	4.6×10^1	2.7×10^2
Diesel fuel, m^3	8.1×10^4	5.7×10^3	8.7×10^4	7.3×10^4	5.7×10^3	7.9×10^4
Gasoline, m^3	1.3×10^3	3.4×10^2	1.6×10^3	3.7×10^3	3.4×10^2	4.1×10^3
Electricity, kWh	8.6×10^7	1.9×10^8	2.7×10^8	6.9×10^8	1.9×10^8	8.8×10^8
Coal,[d] tonne	6.1×10^4	6.3×10^4	1.2×10^5	4.7×10^5	6.3×10^4	5.3×10^5
Manpower, man-hour	1.8×10^6	1.9×10^6	3.7×10^6	5.0×10^6	1.9×10^6	6.9×10^6

a. A large portion of these construction materials may be recyclable, if desired.

b. In stainless steel.

c. In buried spent fuel or reprocessing waste.

d. Total coal for generation of process steam and building heat and generation of electrical energy at coal-fired utilities.

TABLE VI-2 (Continued)

Resource Commitments in U.S. and Global Commons from the Foreign Fuel Increment, Other than Land

Resource	*Case H* — *Fuel Shipped to U.S. - Later Disposed of in a Geologic Repository (Option 1 Fuel Schedule)* — *1985 Geologic Repository Startup* — *Interim*	*Disposition*	*Total*	*1995 Geologic Repository Startup* — *Interim*	*Disposition*	*Total*
Water, m^3	1.8×10^5	1.8×10^4	2.0×10^5	2.5×10^6	2.8×10^4	2.5×10^6
Materials:						
Concrete, m^3	8.1×10^2	1.9×10^3	2.7×10^3	4.1×10^3	2.4×10^3	6.4×10^3
Steel, tonne	5.2×10^2	3.3×10^3	3.8×10^3	3.0×10^3	4.9×10^3	7.9×10^3
Copper,[a] tonne	1.1×10^0	3.8×10^0	4.9×10^0	5.8×10^0	3.8×10^0	9.5×10^0
Zinc,[a] tonne	2.0×10^0	9.3×10^{-1}	2.9×10^0	9.9×10^0	9.3×10^{-1}	1.1×10^1
Aluminum,[a] tonne	0	7.0×10^{-1}	7.0×10^{-1}	0	7.0×10^{-1}	7.0×10^{-1}
Lumber, m^3	4.8×10^1	5.5×10^1	1.0×10^2	2.3×10^2	5.5×10^1	2.9×10^2
Lead,[a] tonne	0	0	0	0	0	0
Depleted uranium,[a] tonne	0	0	0	0	0	0
Chromium[a] in S.S.,[b] tonne	3.1×10^1	0	3.1×10^1	2.4×10^2	0	2.4×10^2
Nickel[a] in S.S.,[b] tonne	1.4×10^1	0	1.4×10^1	1.1×10^2	0	1.1×10^2
Uranium,[c] tonne	0	2.1×10^3	2.1×10^3	0	2.1×10^3	2.1×10^3
Plutonium,[c] tonne	0	1.3×10^1	1.3×10^1	0	1.3×10^1	1.3×10^1
Zirconium,[c] tonne	0	4.1×10^2	4.1×10^2	0	4.1×10^2	4.1×10^2
Energy:						
Propane, m^3	2.1×10^1	2.3×10^1	4.5×10^1	1.1×10^2	2.3×10^1	1.3×10^2
Diesel fuel, m^3	3.1×10^4	2.9×10^3	3.4×10^4	3.7×10^4	2.9×10^3	3.9×10^4
Gasoline, m^3	3.7×10^2	1.7×10^2	5.4×10^2	1.8×10^3	1.7×10^2	2.0×10^3
Electricity, kWh	2.4×10^7	9.6×10^7	1.2×10^8	3.7×10^8	9.6×10^7	4.7×10^8
Coal,[d] tonne	1.7×10^4	3.2×10^4	4.9×10^4	2.4×10^5	3.2×10^4	2.7×10^5
Manpower, man-hour	6.1×10^5	9.6×10^5	1.6×10^6	2.3×10^6	9.6×10^5	3.2×10^6

a. A large portion of these construction materials may be recyclable, if desired.

b. In stainless steel.

c. In buried spent fuel or reprocessing waste.

d. Total coal for generation of process steam and building heat and generation of electrical energy at coal-fired utilities.

TABLE VI-3

Permanent Land Commitment in the World from the Foreign Fuel Increment, Acres[a]

	Case A, B or C	Case D		Case E
	Fuel Remains in Foreign Countries (Option 3 Fuel Schedule)	*Fuel Shipped to U.S. - Later Disposed of in a Geologic Repository (Option 3 Fuel Schedule)*		*Fuel Shipped to U.S. - Later Returned and Reprocessed (Option 3 Fuel Schedule)*
	1985 Geologic Repository Startup	*1985 Geologic Repository Startup*	*1995 Geologic Repository Startup*	*1985 Geologic Repository Startup*
At Geologic Repositories:				
Surface[b]	28	27	27	28
Subsurface[c]	280	270	270	280

	Case F-1	Case F-2	Case G	
	Fuel Shipped to U.S. - Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule)	*Fuel Shipped to U.S.- Reprocessed in U.S.- Pu and U Returned (Option 3 Fuel Schedule)*	*Fuel Shipped to U.S. - Later Disposed of in a Geologic Repository (Option 2 Fuel Schedule)*	
	1985 Geologic Repository Startup	*1985 Geologic Repository Startup*	*1985 Geologic Repository Startup*	*1995 Geologic Repository Startup*
At Geologic Repositories:				
Surface[b]	28	28	9.1	9.1
Subsurface[c]	280	280	91.0	91.0

	Case H	
	Fuel Shipped to U.S. - Later Disposed of in a Geologic Repository (Option 1 Fuel Schedule)	
	1985 Geologic Repository Startup	*1995 Geologic Repository Startup*
At Geologic Repositories		
Surface[b]	4.4	4.4
Subsurface[c]	44.0	44.0

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a. Following decommissioning of facilities and burial grounds, the only land permanently committed is that utilized at geologic repositories for entombment of foreign spent fuel under consideration, and/or associated wastes.

b. Salt tailings from the geologic repository, if not removed from sites (Reference 1).

c. Activities on land above this subsurface area have restrictions to ensure integrity of the repositories (Reference 1).

TABLE VI-4

Resource Commitments in the World from the Foreign Fuel Increment, Other than Land

Resource	*Case A, B or C* *Fuel Remains in Foreign Countries (Option 3 Fuel Schedule)* *1985 Geologic Repository Startup* Interim	Disposition	Total	*Case D* *Fuel Shipped to U.S. - Later Disposed in a Geologic Repository (Option 3 Fuel Schedule)* *1985 Geologic Repository Startup* Interim	Disposition	Total	*1995 Geologic Repository Startup* Interim	Disposition	Total	*Case E* *Fuel Shipped to U.S. - Later Returned and Reprocessed (Option 3 Fuel Schedule)* *1985 Geologic Repository Startup* Interim	Disposition	Total
Water, m^3	0	5.8×10^5	5.8×10^5	1.8×10^6	1.0×10^5	1.9×10^6	1.2×10^7	1.5×10^5	1.2×10^7	3.1×10^6	6.1×10^6	9.2×10^6
Materials:												
Concrete, m^3	0	7.7×10^4	7.7×10^4	8.0×10^3	1.0×10^4	1.8×10^4	2.3×10^4	1.3×10^4	3.6×10^4	8.7×10^4	8.2×10^4	1.7×10^5
Steel, tonne	1.2×10^3	1.8×10^4	2.0×10^4	6.7×10^3	2.0×10^4	2.6×10^4	1.7×10^4	2.9×10^4	4.6×10^4	1.2×10^5	2.7×10^4	1.5×10^5
Copper,[a] tonne	0	8.0×10^1	8.0×10^1	1.1×10^1	2.1×10^1	3.2×10^1	3.1×10^1	2.1×10^1	5.1×10^1	1.5×10^2	8.8×10^1	2.4×10^2
Zinc,[a] tonne	0	8.7×10^0	8.7×10^0	1.9×10^1	5.1×10^0	2.4×10^1	5.2×10^1	5.1×10^0	5.7×10^1	5.4×10^1	1.1×10^1	6.4×10^1
Aluminum,[a] tonne	0	4.8×10^1	4.8×10^1	0	3.8×10^0	3.8×10^0	0	3.8×10^0	3.8×10^0	2.6×10^1	5.0×10^1	7.6×10^1
Lumber, m^3	0	1.9×10^3	1.9×10^3	4.7×10^2	3.0×10^2	7.7×10^2	1.3×10^3	3.0×10^2	1.6×10^3	2.5×10^3	2.0×10^3	4.5×10^3
Lead,[a] tonne	3.3×10^3	1.7×10^3	5.0×10^3	5.0×10^3	0	5.0×10^3	5.0×10^3	0	5.0×10^3	4.8×10^3	1.7×10^3	6.5×10^3
Depleted uranium,[a] tonne	1.5×10^2	0	1.5×10^2	2.8×10^2	0	2.8×10^2	2.8×10^2	0	2.8×10^2	1.9×10^2	0	1.9×10^2
Chromium[a] in S.S.,[b] tonne	2.2×10^2	1.1×10^2	3.3×10^2	6.1×10^2	0	6.1×10^2	1.5×10^3	0	1.5×10^3	5.8×10^2	1.1×10^2	6.9×10^2
Nickel[a] in S.S.,[b] tonne	9.6×10^1	4.8×10^1	1.4×10^2	2.7×10^2	0	2.7×10^2	6.6×10^2	0	6.6×10^2	2.6×10^2	4.8×10^1	3.0×10^2
Uranium,[c] tonne	0	2.6×10^1	2.6×10^1	0	1.3×10^4	1.3×10^4	0	1.3×10^4	1.3×10^4	0	2.6×10^1	2.6×10^1
Plutonium,[c] tonne	0	1.7×10^{-1}	1.7×10^{-1}	0	8.3×10^1	8.3×10^1	0	8.3×10^1	8.3×10^1	0	1.7×10^{-1}	1.7×10^{-1}
Zirconium,[c] tonne	0	2.6×10^3	2.6×10^3	0	2.6×10^3	2.6×10^3	0	2.6×10^3	2.6×10^3	0	2.6×10^3	2.6×10^3
Energy:												
Propane, m^3	0	5.0×10^3	5.0×10^3	2.1×10^2	1.3×10^2	3.3×10^2	5.7×10^2	1.3×10^2	7.0×10^2	2.9×10^3	5.2×10^3	8.2×10^3
Diesel fuel, m^3	8.5×10^3	5.1×10^5	5.2×10^5	2.5×10^5	1.7×10^4	2.7×10^5	2.2×10^5	1.6×10^4	2.4×10^5	2.1×10^5	5.5×10^5	7.6×10^5
Gasoline, m^3	0	4.1×10^3	4.1×10^3	3.7×10^3	9.3×10^2	4.6×10^3	9.9×10^3	9.3×10^2	1.1×10^4	9.4×10^3	4.5×10^3	1.4×10^4
Electricity, kWh	0	3.1×10^9	3.1×10^9	2.6×10^8	5.2×10^8	7.8×10^8	1.7×10^9	5.2×10^8	2.2×10^9	6.7×10^9	3.5×10^9	1.0×10^{10}
Coal,[d] tonne	0	2.9×10^6	2.9×10^6	1.6×10^5	1.7×10^5	3.4×10^5	1.2×10^6	1.7×10^5	1.3×10^6	1.3×10^6	3.1×10^6	4.4×10^6
Manpower, man-hours	7.0×10^5	8.6×10^7	8.6×10^7	5.6×10^6	5.4×10^6	1.1×10^7	1.3×10^7	5.5×10^6	1.8×10^7	4.0×10^7	8.0×10^7	1.2×10^8

a. A large portion of these construction materials may be recyclable, if desired.

b. In stainless steel.

c. In buried spent fuel or reprocessing waste.

d. Total coal for generation of process steam and building heat and generation of electrical energy at coal-fired utilities.

TABLE VI-4 (Continued)

Resource Commitments in the World for the Foreign Fuel Increment, Other than Land

Resource	*Case F-1* *Fuel Shipped to U.S. - Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule)* *1985 Geologic Repository Startup*			*Case F-2* *Fuel Shipped to U.S. - Reprocessed in U.S. - Pu and U Returned (Option 3 Fuel Schedule)* *1985 Geologic Repository Startup*			*Case G* *Fuel Shipped to U.S. - Later Disposed of in a Geologic Repository (Option 2 Fuel Schedule)* *1985 Geologic Repository Startup*			*1995 Geologic Repository Startup*		
	Interim	*Disposition*	*Total*	*Interim*	*Disposition*	*Total*	*Interim*	*Disposition*	*Total*	*Interim*	*Disposition*	*Total*
Water, m^3	3.0×10^6	5.3×10^6	8.3×10^6	3.0×10^6	5.3×10^6	8.3×10^6	6.7×10^5	3.6×10^4	7.1×10^5	4.9×10^6	5.5×10^4	4.9×10^5
Materials:												
Concrete, m^3	8.2×10^4	1.2×10^5	2.0×10^5	8.2×10^4	1.2×10^5	2.0×10^5	2.8×10^3	3.7×10^3	6.5×10^3	8.8×10^3	4.6×10^3	1.3×10^4
Steel, tonne	1.2×10^5	7.6×10^4	1.9×10^5	1.2×10^5	7.6×10^4	1.9×10^5	2.3×10^3	6.5×10^3	8.8×10^3	6.5×10^3	9.7×10^3	1.6×10^4
Copper,[a] tonne	1.4×10^2	1.2×10^2	2.6×10^2	1.4×10^2	1.2×10^2	2.6×10^2	3.9×10^0	7.4×10^0	1.1×10^1	1.2×10^1	7.4×10^0	1.9×10^1
Zinc,[a] tonne	5.0×10^1	1.9×10^1	6.9×10^1	5.0×10^1	1.9×10^1	6.9×10^1	6.7×10^0	1.8×10^0	8.6×10^0	2.0×10^1	1.8×10^0	2.2×10^1
Aluminum,[a] tonne	2.3×10^1	5.4×10^1	7.8×10^1	2.3×10^1	5.4×10^1	7.8×10^1	0	1.4×10^0	1.4×10^0	0	1.4×10^0	1.4×10^0
Lumber, m^3	2.3×10^3	2.5×10^3	4.8×10^3	2.3×10^3	2.5×10^3	4.8×10^3	1.7×10^2	1.1×10^2	2.7×10^2	4.8×10^2	1.1×10^2	5.9×10^2
Lead,[a] tonnes	6.5×10^3	1.7×10^3	8.2×10^3	6.5×10^3	1.7×10^3	8.2×10^3	1.3×10^3	0	1.3×10^3	1.3×10^3	0	1.3×10^3
Depleted uranium, tonne	4.0×10^2	0	4.0×10^2	4.0×10^2	0	4.0×10^2	8.6×10^1	0	8.6×10^1	8.6×10^1	0	8.6×10^1
Chromium[a] in S.S.,[b] tonne	7.2×10^2	1.0×10^2	8.2×10^2	7.2×10^2	1.0×10^2	8.2×10^2	2.0×10^2	0	2.0×10^2	5.5×10^2	0	5.5×10^2
Nickel[a] in S.S.,[b] tonne	3.2×10^2	4.6×10^1	3.7×10^2	3.2×10^2	4.6×10^1	3.7×10^2	9.0×10^1	0	9.0×10^1	2.4×10^2	0	2.4×10^2
Uranium,[c] tonne	0	2.6×10^1	2.6×10^1	0	2.6×10^1	2.6×10^1	0	4.2×10^3	4.2×10^3	0	4.2×10^3	4.2×10^3
Plutonium,[c] tonne	0	1.7×10^{-1}	1.7×10^{-1}	0	1.7×10^{-1}	1.7×10^{-1}	0	2.7×10^1	2.7×10^1	0	2.7×10^1	2.7×10^1
Zirconium,[c] tonne	0	2.6×10^3	2.6×10^3	0	2.6×10^3	2.6×10^3	0	8.4×10^2	8.4×10^2	0	8.4×10^2	8.4×10^2
Energy:												
Propane, m^3	9.7×10^2	5.1×10^3	6.1×10^3	9.7×10^2	5.1×10^3	6.1×10^3	7.4×10^1	4.6×10^1	1.2×10^2	2.2×10^2	4.6×10^1	2.7×10^2
Diesel fuel, m^3	3.0×10^5	5.2×10^5	8.2×10^5	5.0×10^5	5.2×10^5	1.0×10^6	8.1×10^4	5.7×10^3	8.7×10^4	7.3×10^4	5.7×10^3	7.9×10^4
Gasoline, m^3	9.1×10^3	6.0×10^3	1.5×10^4	9.1×10^3	6.0×10^3	1.5×10^4	1.3×10^3	3.4×10^2	1.6×10^3	3.7×10^3	3.4×10^2	4.1×10^3
Electricity, kWh	6.6×10^9	5.7×10^9	1.2×10^{10}	6.6×10^9	5.7×10^9	1.2×10^{10}	8.6×10^7	1.9×10^8	2.7×10^8	6.9×10^8	1.9×10^8	8.8×10^8
Coal,[d] tonne	1.4×10^6	3.6×10^6	5.0×10^6	1.4×10^6	3.6×10^6	5.0×10^6	6.1×10^4	6.3×10^4	1.2×10^5	4.7×10^5	6.3×10^4	5.3×10^5
Manpower, man-hours	3.7×10^7	6.9×10^7	1.1×10^8	4.0×10^7	6.9×10^7	1.1×10^8	1.8×10^6	1.9×10^6	3.7×10^6	5.0×10^6	1.9×10^6	6.9×10^6

a. A large portion of these construction materials may be recyclable, if desired.

b. In stainless steel.

c. In buried spent fuel or reprocessing waste.

d. Total coal for generation of process steam and building heat and generation of electrical energy at coal-fired utilities.

TABLE VI-4 (Continued)

Resource Commitments in the World from the Foreign Fuel Increment, Other than Land

Resource	*Case H* *Fuel Shipped to U.S. — Later Disposed of in a Geologic Repository (Option 1 Fuel Schedule)*					
	1985 Geologic Repository Startup			*1995 Geologic Repository Startup*		
	Interim	*Disposition*	*Total*	*Interim*	*Disposition*	*Total*
Water, m^3	1.8×10^5	1.8×10^4	2.0×10^5	2.5×10^6	2.8×10^4	2.5×10^6
Materials:						
Concrete, m^3	8.1×10^2	1.9×10^3	2.7×10^3	4.1×10^3	2.4×10^3	6.4×10^3
Steel, tonne	7.8×10^2	3.3×10^3	4.1×10^3	3.3×10^3	4.9×10^3	8.2×10^3
Copper,[a] tonne	1.1×10^0	3.8×10^0	4.9×10^0	5.8×10^0	3.8×10^0	9.5×10^0
Zinc,[a] tonne	2.0×10^0	9.3×10^{-1}	2.9×10^0	9.9×10^0	9.3×10^{-1}	1.1×10^1
Aluminum,[a] tonne	0	7.0×10^{-1}	7.0×10^{-1}	0	7.0×10^{-1}	7.0×10^1
Lumber, m^3	4.8×10^1	5.5×10^1	1.0×10^2	2.3×10^2	5.5×10^1	2.9×10^2
Lead,[a] tonne	6.5×10^2	0	6.5×10^2	6.5×10^2	0	6.5×10^2
Depleted uranium,[a] tonne	4.3×10^1	0	4.3×10^1	4.8×10^1	0	4.8×10^1
Chromium[a] in S.S.,[b] tonne	7.8×10^1	0	7.8×10^1	2.8×10^2	0	2.8×10^2
Nickel[a] in S.S.,[b] tonne	3.5×10^1	0	3.5×10^1	1.3×10^2	0	1.3×10^2
Uranium,[c] tonne	0	2.1×10^3	2.1×10^3	0	2.1×10^3	2.1×10^3
Plutonium,[c] tonne	0	1.3×10^1	1.3×10^1	0	1.3×10^1	1.3×10^1
Zirconium,[c] tonne	0	4.1×10^2	4.1×10^2	0	4.1×10^2	4.1×10^2
Energy:						
Propane, m^3	2.1×10^1	2.3×10^1	4.5×10^1	1.1×10^2	2.8×10^1	1.3×10^2
Diesel fuel, m^3	3.1×10^4	2.9×10^3	3.4×10^4	3.7×10^4	2.9×10^3	3.9×10^4
Gasoline, m^3	3.7×10^2	1.7×10^2	5.4×10^2	1.8×10^3	1.7×10^2	2.0×10^3
Electricity, kWh	2.4×10^7	9.6×10^7	1.2×10^8	3.7×10^8	9.6×10^7	4.7×10^8
Coal,[d] tonne	1.7×10^4	3.2×10^4	4.9×10^4	2.4×10^5	3.2×10^4	2.7×10^5
Manpower, man-hours	6.1×10^5	9.6×10^5	1.6×10^6	2.3×10^6	9.6×10^5	3.2×10^6

a. A large portion of these construction materials may be recyclable, if desired.

b. In stainless steel.

c. In buried spent fuel or reprocessing waste.

d. Total coal for generation of process steam and building heat and generation of electrical energy at coal-fired utilities.

and VI-3 is that portion of the total land which is consumed by implementation of the particular case. For example, in Case D, the 13,600 MTU of foreign spent fuel occupies about 14% of the 810-hectare (2000-acre) geologic repository; therefore, the subsurface land commitment is 108 hectares (270 acres).

Some construction materials (identified in Tables VI-2 and VI-4) are expected to be recycled. After decontamination of ISFS facilities and transportation casks, large portions of certain materials could be recycled if desired. For example, almost all the stainless steel in ISFS facilities (up to 6,700 tonnes for pool liners and storage baskets) may be recycled.

REFERENCE FOR SECTION VI

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

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

In this section, the short-term and long-term effects on the environment are compared if the foreign fuel offer of the U.S. Spent Fuel Storage Policy is implemented or is not implemented. Short-term effects are considered to be those that occur during the period of the construction and operational phases of the facilities. Long-term effects are those that extend past this period into the indefinite future. The short-term effects are the trade-offs in land use and the radiological and nonproliferation impacts on the environment. Long-term effects are associated with conservation of resources and allowable land use.

The purpose of providing storage for foreign spent fuels in the U.S. is to reduce the potential for nuclear weapon proliferation. The short-term and long-term effect on the environment resulting from implementation of the policy must be balanced against the major objective of reducing the potential for nuclear weapon proliferation. Although not readily quantifiable, any reduction in proliferation potential is a major environmental and societal benefit. In this statement, if the policy is not implemented, nuclear fuel reprocessing is assumed to be introduced into a number of foreign countries, and this may result in a significant increase in nuclear weapon proliferation by making plutonium easier to obtain.

The differences in resource use between all cases considered in this volume are small and will not foreclose future options except to the extent that the resources are consumed. The consumption associated with the foreign fuel increment is a very small fraction of available resources.

A. Short-Term Effects

Construction of facilities, supporting services such as roads, railroads, and transmission lines, and operation of these facilities will cause short-term effects on the environment. These are regarded as slight changes having essentially no long-term impact. Construction and operation of the U.S. facilities will be under NRC licensing and will conform to EPA standards to minimize the impact on the environment. Controls equivalent to those of the U.S. are assumed to apply for foreign facilities. These controls will be administered by some international agency such as the IAEA. Less extensive control may be enforced if the policy is not implemented or if international controls are not enforced. These less effective controls would result in larger environmental effects than indicated in this volume. Land used for ISFS basin facilities will be available for other unrestricted uses when restored after decommissioning.

Some land associated with reprocessing plants may be committed indefinitely. However, the decommissioning mode assumed in this EIS is dismantlement of facilities and complete restoration of used lands. Even if complete restoration of these lands is not possible, the permanent commitment of these lands would be smaller than the lands committed for the geologic repository. The lands used for receiving the foreign spent fuel would be a small portion of those committed from receiving domestic spent fuel.

B. Long-Term Effects

The major long-term effect on the environment is the commitment of land at the geologic repositories to dispose permanently of the long-lived radionuclides in the spent fuel. Careful consideration of this action is appropriate; however, long-term isolation is required if spent fuel is ultimately disposed of as waste or if waste from reprocessing is disposed of. The site used for the repositories will be selected to minimize losses in long-term productive use of the land. The land selected will constitute a very small fraction of available U.S. and foreign land surface area. The land area above the 810-hectare (2000-acre) repositories will require permanent restrictions to ensure the integrity of the repositories. All subsurface activities (such as mining or drilling) will be prohibited. Surface land activities that do not imperil the integrity of the repository will be unrestricted. In this volume, it is assumed that the repository is in a salt formation and that the mined salt will be permanently stored on the site. However, the salt tailings may be removed for commercial use or disposal elsewhere. The land occupied by the burial grounds may be restricted for several hundred years until the radioactivity in trenches decay to innocuous levels.

If the foreign fuel offer is accepted, the resource commitment will be small as can be seen from Section VI. No strategic resources will be committed as a result of this action. If the offer is not made to accept the foreign fuels, the total world resources committed will be equivalent to those committed if the policy is implemented; but the U.S. commitment would be reduced.

VIII. ENVIRONMENTAL TRADEOFF ANALYSIS

A. Introduction

The elements to be weighed in the environmental tradeoff analysis in this volume include the environmental benefits and costs associated with the U.S. Spent Fuel Storage Policy.

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 of 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 were covered by the draft EIS. Nine cases were analyzed for U.S. policy implemented and U.S. policy not implemented for foreign spent fuel. 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 time period 1997 to 2006. To demonstrate the effects of delayed repository opening beyond the year 1995, an appendix was prepared for this volume (Appendix A) to show the environmental effects with the first repository startup in the year 2010.

The two cases used to show the environmental effect comparison of initial geologic repository startup in the year 2010 were selected to parallel Cases A and G in the body of this volume. These two cases (called Case I and J) were selected to differentiate between the cases which consider earlier startup dates for the geologic repository.

Based upon the President's statement of April 7, 1977, the national interest will be served by encouraging delay by other nations in conventional reprocessing until more proliferation-resistant technologies and/or institutional arrangements can be developed. The U.S. offer to accept limited quantities of foreign spent power reactor fuel for storage in this country in conjunction with the proposed program for storing spent fuel from domestic utilities can contribute to this and other nonproliferation objectives. For nations that have no option other than reprocessing, storage in the U.S. offers an alternative (acceptable from a nonproliferation point of view) for disposing of their spent fuel.

If foreign spent fuel is stored in the U.S., time would then be available for interested and eligible countries to build local storage capability or to investigate development of regional, multinational, or international storage facilities, as well as time to evaluate and develop more proliferation-resistant technologies and/or institutional arrangement for their fuel cycles. If eligible countries take advantage of the U.S. offer, then such actions may assist in promoting an international consensus favoring a delay in moving to the plutonium economy and limitations on the spread of reprocessing plants.

Removal of spent fuel from sensitive regions may contribute to a reduction of tensions and improve confidence in the observance of nonproliferation obligations and intentions. Pairs of countries may find such spent fuel removal beneficial in building mutual confidence. Finally, nonproliferation treaty adherence and other safeguards and nonproliferation-related developments may be encouraged.

Costs are involved in implementing the U.S. offer. The opportunity to store spent fuel in the U.S. could reduce the incentive for some nations to arrive at their own solutions to spent fuel and waste disposition. There would likely be increased shipment of spent fuel on the high seas. However, it is not clear that this would involve an increased environmental risk to the global commons since it is likely that shipments of spent fuel would take place among countries even in the absence of a U.S. spent fuel storage offer. Moreover, an indeterminate number of these shipments are likely to be for reprocessing and may involve return shipments of waste, separated plutonium and/or mixed oxide fuels which also pose environmental risks.

Some incremental cost to the U.S. is involved in the additional land, water, and other resources required for implementing storage for foreign fuel in addition to domestic fuel. However, the quantity of the resources involved is small. The U.S. will obtain export earnings from the storage fee and from the transportation charges paid to U.S. carriers transporting spent fuel from U.S. ports to the storage facility. The storage fee will be set so that the U.S. Government recovers all costs.

Some incremental environmental hazard is also involved because foreign spent fuel will introduce additional sources of radiation into this country. However, in comparison to the risks involved in shipping and storing domestic spent fuel, the additional risk introduced from foreign fuel is small. Under Option 3, the maximum quantity of spent fuel that would be introduced into the U.S. between the years 1983 and 2000 is 13,6000 MTU, representing 19% of the domestic spent fuel stored. Nevertheless, the shipment of foreign fuel through U.S. ports of entry would expose new areas and travel routes to potential radiation hazards and the risks associated with accidents in handling and transportation of spent fuel casks.

In summary, implementation of the U.S. offer to store foreign spent fuel would involve a tradeoff between the potential gains for nonproliferation policy and the additional risks to the environment posed by the transportation and storage of foreign fuel within the United States. With respect to the global commons, the tradeoff of environmental impacts is unclear and depends upon 1) the risks of additional spent fuel shipments as weighed against the risks of shipments which would take place anyway, and 2) the potential risks associated with any reprocessing and subsequent disposition of plutonium and wastes that may take place in the absence of a U.S. offer. World environmental effects are also given for completeness.

The environmental tradeoff analysis presented in the remainder of this section summarizes and compares the environmental effects, nonproliferation effects, use of resources, and other pertinent factors associated with the cases considered in this environmental statement.

B. Summary of Environmental Effects

The environmental effects, other than nonproliferation, believed to be significant in the cases considered in this volume are the radiation exposure of the public, occupational radiation exposure, radiological health effects, and nonradiological deaths resulting from accidents. Some of the cases in this analysis include reprocessing of foreign fuel. When uranium and plutonium are recovered and recycled, the need for virgin uranium decreases, thereby decreasing mining and milling at the front end of the fuel cycle. Decreases in mining and milling results in a significant decrease in occupational and population radiological health effects and deaths from occupational accidents and is discussed in Section III. However, in this environmental tradeoff analysis, mining and milling environmental effects are not included because they are not directly associated with the operations at the back-end of the fuel cycle that are directly affected by the Spent Fuel Policy. Environmental effects of each case considered are shown in two ways, i.e., 1) U.S. and global commons and 2) world. In this EIS, environmental effects in the U.S. and global commons are equal to the world environmental effects less those associated with regional effects resulting from operations in foreign nations.

The environmental effects are summarized in Tables VIII-1 and VIII-2 for Cases A through H and Table VIII-3 for Cases I and J.

C

TABLE VIII-1

Summary of Environmental Effects From Interim[a] Storage of Foreign Spent Fuel

	A,B,C[b]	*D*	*D*	*E*	*F-1*	*F-2*	*G*[c]	*G*[c]	*H*[c]	*H*[c]
Year U.S. Geologic Repository Begins Initial Operation	1985	1985	1995	1985	1985	1985	1985	1995	1985	1995
Population Whole Body Dose Commitment, man-rem										
U.S. and Global Commons	0[d]	730	2840	980	1000	1000	170	1040	47	550
World	2.5	730	2840	980	1000	1000	174	1040	47	550
Occupational Exposure, man-rem										
U.S. and Global Commons	0[d]	440	1220	345	510	510	138	450	73	190
World	16	510	1270	370	570	580	157	470	82	200
Health Effects[e]										
U.S. and Global Commons	0[d]	0.74	2.5	0.83	0.96	0.96	0.19	0.93	0.08	0.46
World	0.01	0.78	2.6	0.85	1.0	1.0	0.21	0.94	0.08	0.47
Accidental Deaths										
7-j *U.S. and Global Commons*	0[d]	1.6	2.4	0.87	1.8	1.8	0.47	0.82	0.22	0.38
World	0.4	1.6	2.4	1.2	1.8	1.8	0.47	0.82	0.22	0.38

C

a. Does not include incremental environmental effects of mining and milling.

b. Case A effects are shown. The effects for Cases B and C are essentially the same.

c. Case G includes environmental impacts for receipt of Option 2 spent fuel in the U.S., and Case H includes environmental impacts for receipt of Option 1 spent fuel in the U.S.

d. In Case A no operations occur in the U.S. or the global commons. For Cases B and C, there are no operations with foreign spent fuel in the U.S. but some fuel may be shipped by sea between countries other than the U.S.

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. 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 Volume 2 for more detail on methodology used in determining health effects.)

C TABLE VIII-2

Summary of Major Environmental Effects from Interim Storage and Disposition of Foreign Spent Fuel

	A,B,C[a]	D	D	E[a]	F-1[a]	F-2[a]	G[b]	G[b]	H[b]	H[b]
Year U.S. Geologic Repository Begins Initial Operation	1985	1985	1995	1985	1985	1985	1985	1995	1985	1995
Population Whole Body Dose Commitment, man-rem										
U.S. & Global Commons	5500	850	2950	6930	11,500	11,500	198	1080	67	570
World	7200	850	2950	8260	11,500	11,500	202	1080	67	570
Occupational Exposure, Man-rem										
U.S. & Global Commons	0	700	1480	440	5810	6060	228	540	118	235
World	8700	770	1530	7910	5870	6210	247	560	127	245
Health Effects[c]										
U.S. & Global Commons	3.2	1.02	2.8	4.3	11.1	11.3	0.28	1.02	0.12	0.51
World	10.5	1.06	2.8	10.6	11.1	11.4	0.30	1.03	0.13	0.52
Accidental Deaths										
7-j *U.S. & Global Commons*	0	3.4	4.2	1.6	9.4	10.6	1.1	1.5	0.56	0.72
World	7.9	3.4	4.2	8.3	9.4	10.9	1.1	1.5	0.56	0.72

C *a.* Does not include incremental environmental effects of mining and milling. In Cases A,D,C,E, F-1 and F-2, it is assumed the foreign spent fuel is reprocessed and the recovered plutonium and uranium is recycled; reduced mining and milling requirements would result in a decrease of ~120 health effects (because of reduced lung exposure to the population and work force) and a decrease of ~31 in occupational deaths.

b. Case G includes environmental impacts for receipt of Option 2 spent fuel in the U.S. and Case H includes environmental impacts for receipt of Option 1 spent fuel in the U.S.

c. 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 Volume 2 for more detail on methodology used in determining health effects.)

C TABLE VIII-3

Summary of Major Environmental Effects for Interim Storage of Foreign Fuel, 2010 U.S. Geologic Repository Startup[a]

Year U.S. Geologic Repository Begins Initial Operation	*Case I* 2010	*Case J* 2020
Population Whole Body Dose Commitment, man-rem		
U.S. and Global Commons	1400	0
World	1400	8.5
Occupational Exposure, man-rem		
U.S. and Global Commons	330	0
World	360	43
Health Effects[b]		
U.S. and Global Commons	1.0	0
World	1.1	0.04
Accidental Deaths		
U.S. and Global Commons	0.5	0
World	0.5	0.1

a. Option 2 Fuel Schedule used for these cases.

b. Serious somatic and genetic 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 under this column along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

These effects are the increments associated with foreign fuel and do not include the larger effects associated with interim storage and disposition of U.S. spent fuel. Tables VIII-1 and VIII-3 summarize the effects of interim operation (i.e., that of spent fuel transport from reactors to the ISFS facilities and disposition facility, and receipt and interim storage in the ISFS facilities). Table VIII-2 gives the environmental effects of interim operations and also the effects of disposition. Interim effects are directly comparable with the effects given in Volume 2 for U.S. spent fuel. In some instances, all of the operations occur in the foreign countries (in Cases A, B, C, and J); and, in those instances, only the effects of worldwide recycling of radionuclides released from these facilities are included in the U.S. and global commons.

The analyses show that there are no substantial radiological health impacts whether the policy is implemented or not for foreign spent fuel. This statement is correct for both interim and interim plus disposition operation. The radiological exposure expressed as whole body dose commitment for U.S. and global commons and for the world is smallest (67 to 1400 man-rem) for the cases involving storage of foreign spent fuel in the U.S. with disposition in a U.S. geologic repository (Cases D, G, H and I). It is greatest (about 11,500 man-rem) when foreign spent fuel is reprocessed in the U.S. (Cases F-1 and F-2). Population doses shown in Tables VIII-1 and VIII-2 are a very small fraction of the whole body exposure of about 2 x 10^{11} man-rem from natural radiation sources in the same period. The world population dose commitment in Table VIII-3 should be compared to 3.7 x 10^{11} man-rem. This comparison value is higher than that used for Tables VIII-1 and VIII-2 due to different lengths of the operating period.

Occupational radiation exposures range up to 6060 man-rem (Case F-2) in the U.S. and global commons. World occupational exposures range from a minimum of 130 man-rem (Case H) to a maximum of 8700 man-rems (Cases A, B, and D).

The number of radiological health effects associated with population and occupational dose commitment over the operating period and the next 100 years ranges from about 0.1 to about
7-a 12 in the U.S. and global commons and the world. For perspective, 120,000,000 health effects are expected to occur within the world population from natural radiation during this same period considered in Tables VIII-1 and VIII-2. If the period is extended to include that used in Table VIII-3 the expected health effects will be 200,000,000 from natural radiation. The largest number of health effects (about 12) is associated with cases involving reprocessing in the U.S. (Cases F-1 and F-2) because they involve the largest number of workers and the longest period of operations.

The case with the lowest number of radiological health effects (in both the U.S. and global commons and in the world) is Case H, the one associated with receipt of the smallest amount of foreign spent fuel. The relationship between health effects and the annual
C spent fuel received is shown in Table VIII-4.

The estimated number of deaths in the work force from non-radiological accidents during the operation periods ranges from
C 0 to 11 for the U.S. and global commons for the world. These numbers are small fractions of the 12,500 deaths from occupational accidents in the U.S. alone during the year 1976.

The environmental risks (where risk is the product of the probability and consequences of an event) from major abnormal events and accidents in the facilities involved with foreign spent fuel are very small (0.06 to 0.6 mrem) and essentially the same
C for Cases A through H. These risks were not determined for Cases I and J, but the risks would be proportional to Cases G and A respectively corrected for the changes in program size and program duration. The maximum dose commitment to an offsite individual following abnormal natural events (e.g., tornadoes) and severe accidents (e.g., criticality) at the facilities is well below one rem, and the probability of these events occurring is low. Transportation accidents involving foreign fuel that result in the loss of containment could lead to greater consequences. The maximum consequences would be expected from an accident involving breaching of a low-level TRU waste container. In this accident, the maximum whole body dose to an individual would be about four rem, and the associated dose risk is estimated to be about 0.01 mrem (whole body) over the entire campaign. The dose risk to the maximum individual from accidents involving spent fuel
8-b shipments is estimated to be 0.06 mrem over the entire campaign. No near-term biological effects from exposure to radiation are expected for any of the accidents analyzed.

C. Summary of Proliferation Effects

The purpose of providing U.S. spent fuel storage for foreign fuels is to reduce the potential for proliferation of sensitive nuclear materials. Although not readily quantifiable, any reduction in proliferation potential is an environmental and societal benefit. For purposes of comparing the proliferation effects of the various cases analyzed in this volume, the following assumptions are made:

- Disposal of fuel in a geologic repository greatly reduces the risk of diversion and furthers U.S. proliferation potential.
- If fuel is reprocessed in the U.S. or abroad under international safeguards and proliferation-resistant technologies, the risks of diversion and proliferation are reduced.

C TABLE VIII-4

Radiological Health Effects for Fuel Schedules Considered

		Health Effects[a,b]	
Fuel Schedules	*Amount of Fuel Through the Year 2000, MTU*	*Repository Startup 1985*	*Facility Startup 1995*
Option 1 - Countries in Sensitive Regions	2,160	0.1	0.5
C Option 2 - Nonproliferation Benefits - Low Option	4,350	0.3	1.0
E Option 3 - Nonproliferation Benefits - High Option	13,600	1.1	2.8

C *a.* Health effects resulting from radiation exposure (including occupational exposures and dose commitment to world population). Health effects from organ doses are not shown independently, but these organ health effects are included under these columns along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

b. Health effects shown for Case H (Option I fuel schedule), Case G (Option 2), and Case D (Option 3). Operations are the same in these three cases.

C In the context of the U.S. nonproliferation goals, Cases A and J are least acceptable. In Cases A and J, the U.S. takes no action in regard to storage of spent fuel from foreign power reactors. Some nations lacking sufficient storage capability may turn to reprocessing as an alternative. Thus, additional countries may acquire facilities capable of producing material usable in nuclear explosive devices; and these sensitive materials may be stored inside many countries, some located inside sensitive regions. If this case were adopted, the U.S. would limit its opportunity to promote its nonproliferation goals to forestall the introduction of reprocessing plants and to decrease the widespread national storage of spent fuel containing plutonium.

Spent fuel remains in foreign countries in Cases B and C. In these cases, the U.S. would support either multinational storage (Case B) or national storage (Case C). The nonproliferation benefits of multinational storage are more beneficial than national storage because the countries eligible for bilateral support of multinational storage would have to be outside sensitive regions. The countries would also have to show financial capability to support an expanded spent fuel storage program once U.S. assistance stops. Multinational storage provides for removal of fuel from sensitive countries. Multinational ownership and/or operation of spent fuel storage facilities would also provide an additional barrier to diversion of material for reprocessing to obtain materials that could be used in nuclear weapons. National storage (Case C) would provide no fuel storage for countries in sensitive regions, and by itself, would not achieve the nonproliferation goals of the U.S. This option could be used along with other options (i.e., Case H) for fuel from sensitive countries to implement the U.S. nonproliferation goals.

In Cases D, E, F-1, and F-2, spent fuel is stored in the U.S.; and the Option 3 fuel schedule, the highest level of foreign country participation, is assumed. These cases include:

1) Disposition of foreign fuel in a U.S. geologic repository (Case D).

2) Return of foreign fuel for reprocessing under conditions that meet nonproliferation objectives (Case E).

3) Reprocessing of foreign fuel and recycling of uranium and plutonium in the U.S. (Case F-1).

4) Reprocessing of foreign fuel in the U.S., and return of fabricated mixed oxide fuel to foreign countries not in sensitive regions (Case F-2).

In Cases E, F-1, and F-2, the foreign spent fuel is assumed to be reprocessed, and as stated previously, if the U.S. agrees to reprocessing of the fuel, reprocessing must be carried out under international safeguards by using proliferation-resistant technologies which meet the nonproliferation objectives of the United States.

Cases G, H, and I are similar to Case D in that foreign fuel is stored in the U.S. and later disposed of in a U.S. geologic repository. The differences in these cases are the types of countries included in the policy and the amount of foreign fuel received by the United States. Case H (Option 1 — the least amount of foreign fuel) involves only countries inside sensitive regions. Cases G and I (Option 2) involve countries inside sensitive regions plus other countries with clearly identified spent fuel storage problems (from a nonproliferation standpoint). Case D (Option 3 — largest amount of foreign fuel) includes countries in Cases G and I, plus a larger number of non-nuclear-weapons states. In Case H, the spent fuel is removed from countries in sensitive regions. Removal of this fuel is a major objective of the U.S. nonproliferation policy. However, other foreign nations would have to choose a course of action for storage of their spent fuel. Spent fuel would be stored in a number of locations, and some countries might select reprocessing as an alternative even though adequate safeguards to achieve an adequate level of nonproliferation are not available. Larger, industrialized nations are better able to finance spent fuel storage facilities. However, they are more likely to construct a reprocessing plant, either jointly or on an individual basis. Therefore, in Case D, which includes larger, industrialized non-nuclear weapon nations, the highest benefits to the nonproliferation policy are offered.

D. Summary of Commitment of Resources

Resources considered for Cases A through H in this volume that are committed in an irreversible and irretrievable manner are 1) land areas permanently affected, 2) manpower, and 3) materials consumed, such as fuels, chemicals, and construction materials. Resources committed for Cases I and J were not analyzed in Appendix A but would be proportional to Cases G and A respectively corrected for the changes in program size and duration.

Permanent land commitment is associated with geologic repositories and is shown in Tables VI-1 and VI-3 of Section VI. Surface land commitment in the U.S. and global commons ranges from none (Cases A, B, C, and E) to 11 hectares (28 acres) (Cases F-1 and F-2) and subsurface land from none (Cases A, B, C, and E) to 113 hectares (280 acres) (Cases F-1 and F-2) and is associated with waste disposal in geologic repositories. Land commitment is least when no foreign fuel is retained in the U.S. and is greatest when foreign fuel is reprocessed and the reprocessing waste stored in U.S. geologic repositories. Permanent surface land commitment in the world ranges from 2 hectares (5 acres) (Case H) to 11 hectares (28 acres) (Cases A, B, C, E, F-1, and F-2) and subsurface land from 18 hectares (44 acres) (Case H) to 113 hectares (280 acres) (Cases A, B, C, E, F-1, and F-2). The amount of land committed in the world is approximately the same for cases assuming the same amount of fuel stored. The smaller land commitments are associated with those cases involving a smaller amount of foreign fuel (Cases G and H).

Manpower requirements (Table VI-2 of Section VI) in the U.S. and global commons range from none (Case A) to about 1×10^8 man-hours (Cases F-1 and F-2). The least requirement is when no foreign fuel is shipped to the U.S.; the greatest requirement is when foreign fuel is reprocessed, and the reprocessing waste is stored in U.S. geologic repositories. World manpower requirements (Table VI-4 of Section VI) range from 1.6×10^6 man-hours (Case H) to 1×10^8 man-hours (Cases E, F-1, and F-2). The least requirement is associated with Case H, the low fuel schedule (Option 1). The greatest requirement is when foreign fuel is shipped to the U.S. and is later reprocessed, either in the U.S. or foreign nations (Cases E, F-1, and F-2).

The use of natural resources (materials and energy) is
C | nominal, and in Cases A through H, is a small fraction of 1% of the annual production and/or consumption in the United States. Construction materials, fuel and electricity use (Table VI-2 of Section VI) in the U.S. and global commons are least for cases where no foreign fuel is shipped to the U.S. (Cases A, B, C) and greatest when foreign fuel is reprocessed and the reprocessing waste stored in a U.S. geologic repository (Case F-1). Resource uses in the world (Table VI-4 of Section VI) are least for the
C | low fuel schedule (Option 1 - Case H). Resource use is greatest for the cases when foreign fuel is shipped to the U.S. for interim storage and is later reprocessed in the U.S. or in foreign nations (Cases E, F-1, and F-2).

E. Additional Considerations

E.1 Cask Availability

Foreign spent fuel will likely be shipped by foreign countries in casks of foreign origin. The numbers of foreign casks needed for shipments of the foreign spent fuel to the U.S. and any returns are shown in Table VIII-5 for Cases A through I. Cask needs for Case J would be roughly 1/3 of those shown for Case A in Table VIII-5 since Option 2 fuel schedule was assumed for that case. Some foreign countries currently have a viable cask fabrication industry and foreign industrial capabilities are expected to expand to provide the casks as the number required gradually increases through the year 2000.

For disposition activities within the U.S., it is assumed that foreign spent fuel and radioactive wastes (from reprocessing) will be transported in casks of U.S. origin.

For Cases D, G, H, or I involving intra-U.S. shipments of foreign fuel from an ISFS facility to a geologic repository, additional casks will be required five years earlier than would be the case if only U.S. fuel were being shipped to the repository. This earlier need of casks for shipment of foreign fuels results in an earlier expenditure of money for cask fabrication than would be the case if no foreign fuel were being shipped within the United States. The additional domestic casks required to transport foreign fuel from ISFS or geologic facilities to a U.S. reprocessing plant (Cases F-1 and F-2) and the reprocessing wastes to a geologic repository are needed when reprocessing begins. Cask requirement for intra-U.S. shipments of foreign fuel and of waste from reprocessing are shown in Table VIII-6.

E.2 Siting/Ownership Questions

In the cases in which foreign fuel is not shipped to the U.S. but is stored in foreign multinational or national ISFS facilities, as would be agreed upon in bilateral or multinational treaties (Cases B and C), timely implementation of these actions could be affected by special siting and/or ownership considerations. A delay in policy implementation could result from lack of acceptance by one or more countries of the terms of U.S. support of spent fuel storage arrangements abroad, including:

- Ownership arrangements (i.e., financing/cost programs)
- Operational control arrangements
- Transportation policy

TABLE VIII-5

Foreign Casks Needed for Shipment of Foreign Fuel

Case Description		*Geologic Repository Startup*	*Spent Fuel Casks*	*High-Level Waste Casks*	*Intermediate Level Waste Casks*
Fuel Remains in Foreign Countries (Option 3 Fuel Schedule)	A, B, & C	1985	23[a]	2	10
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 3 Fuel Schedule)	D	1985	146	0	0
		1995	146	0	0
Fuel Shipped to U.S. - Later Returned for Reprocessing (Option 3 Fuel Schedule)	E	1985	150	2	10
Fuel Shipped to U.S. - Later Reprocessed and Recycled in U.S. (Option 3 Fuel Schedule)	F-1	1985	146	2	10
Fuel Shipped to U.S. - Later Reprocessed in U.S. - Pu and U Returned (Option 3 Fuel Schedule)	F-2	1985	146	2	10
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 2 Fuel Schedule)	G & I	1985	44	0	0
		1995	44	0	0
		2010	44	0	0
Fuel Shipped to U.S. for Storage - Later Disposed of in U.S. Geologic Repository (Option 1 Fuel Schedule)	H	1985	21	0	0
		1995	21	0	0

a. This requirement does not include casks for any shipment by sea that may be arranged for Cases B or C.

C TABLE VIII-6

Schedule of Additional Domestic Casks Needed for Foreign Fuel

Case	*Geologic Repository Startup*	*Year Casks are Needed*	*Number of Casks* Spent Fuel Casks	*High-Level Waste Casks*	*Intermediate-Level Waste Casks*
D	1985	1993	10[a]	-	-
D	1995	2002	18[a]	-	-
E[b]	-	-	-	-	-
F-1, F-2	1985	1998	14[c]	2[c]	10[c]
G	1985	1991	3[a]	-	-
G	1995	2004	8[a]	-	-
H	1985	1991	2[a]	-	-
H	1995	2003	4[a]	-	-
C I	2010	2019	8[a]	-	-

a. Casks for shipment of foreign fuel from ISFS to geologic repository are required 5 years earlier than would be needed for shipments of U.S. fuel from U.S. reactors to geologic storage.

b. No domestic casks used for foreign fuel.

c. Additional casks required for reprocessing operations.

- Long-term disposition policy (i.e., attitude of interested nations toward reprocessing)
- Safeguards policy
- Other considerations.

E.3 Role of International Organizations in Implementation of Policy

C Implementation of most of the cases considered in this volume (Case B - Case I) would require coordinated actions with national and international organizations, such as IAEA, to cooperatively implement the safeguards policies of these organizations. The safety of moving spent fuel across national borders and/or on international waterways, the siting criteria for ISFS facilities in countries that store fuel from other participating countries, and above all, the perceived national and international benefits or storage of this fuel will probably be important factors that organizations will consider in their judgment of the acceptability of the U.S. Spent Fuel Policy.

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).

C APPENDIX A

ENVIRONMENTAL EFFECTS OF DELAYED GEOLOGIC REPOSITORY (STARTUP IN THE YEAR 2010)

A.1 Purpose of Appendix

Due to the uncertainty in the government's program dealing with nuclear waste disposal problems, delays in the opening of the first geologic repository beyond the time frame originally analyzed in this EIS is a possibility. This appendix provides the environmental analysis of interim storage of foreign fuel in the U.S. assuming the initial U.S. geologic repository is started up in the year 2010. Appendix E of Volume 2 shows the environmental effects of a delayed geologic repository for interim U.S. spent fuel storage. When preparation of the draft EISs[1,2] were initiated 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 power reactor fuels in an ISFS facility were calculated for geologic repository operation beginning in the year 1985 or 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 completed, DOE recognized that the first repository might not be in operation until the mid to late 1990s.

President Carter recently announced (February 12, 1980)[3] the administration's position on nuclear waste management and estimated that a decision on the location of the first repository will be made 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 repository may be available between the years 1997-2006. To show the environmental effects of delayed repository opening beyond the year 1995, as analyzed in the body of this EIS on the U.S. Spent Fuel Storage Policy, DOE decided to prepare this appendix to show the environmental effects associated with interim storage of foreign spent power reactor fuel in ISFS facilities with the first geologic repository startup in the year 2010. Startup of the geologic repository in the year 2010, assumed in this appendix, was arbitrarily selected to establish an upper limit for the environmental effects associated with storing spent fuel.

For purposes of the analysis in this appendix, the assumption is made that the U.S. Government would provide sufficient storage capacity to allow receipt of spent fuel from Option 2 (mid-range) countries into the U.S. for storage in ISFS facilities. The spent fuel selected for receipt under this U.S. policy implementation would provide a nonproliferation benefit to the U.S. This appendix

C compares the environmental effects of the delay in startup of the geologic repository if the U.S. Spent Fuel Storage Policy is implemented or not implemented for foreign fuel. Three foreign fuel schedules are discussed in Section II of this volume to show the range of foreign fuel that may be accepted by the U.S. Government under this policy. The analysis in this appendix selects the "Nonproliferation Benefits Low Option (Option 2)" fuel schedule given in Table II-1 of Section II.D of this volume. DOE's proposed action is to implement the policy and the U.S. Government should offer to take title to foreign fuel from Option 2 countries on a case-by-case basis.

The alternatives, called cases in this appendix, used to show the environmental effect comparison of delayed startup of the disposition facility (until the year 2010) were selected to parallel the cases considered in the remainder of this volume of the EIS. Two cases were selected, i.e., that of implementing the Spent Fuel Storage Policy including U.S. acceptance of mid-range amounts of foreign fuel and that of not implementing the policy, thereby causing the foreign fuel to remain abroad and probably be reprocessed. These cases are called Case I and J respectively to help differentiate between cases discussed in the remainder of this volume.

Case I is similar to Case G but fuel in Case I is stored in the U.S. ISFS facilities approximately twice as long. Receipt of foreign fuel in the U.S. will be completed by the year 2000. This case assumes disposal of the foreign fuel in a U.S. geologic repository.

Operations for Case J are the same as for Case A, but in Case J the Option-2 fuel scheduled is assumed, whereas for Case A the Option-3 fuel schedule is assumed. This case assumes that no U.S. action is taken and each foreign country arranges for its own spent fuel to be reprocessed and the recovered uranium and plutonium to be reused.

The case descriptions and their environmental effects are evaluated for implementing or not implementing the policy for the foreign fuels. To show the environmental impact of the foreign spent fuel that may be involved under the U.S. Spent Fuel Storage Policy, this appendix determined the incremental environmental effects associated with only the foreign fuel assumed to be accepted by the U.S. Government. This is the equivalent of the environmental impacts of implementing the foreign portion of the policy. The impact of the policy for the domestic fuels is determined in Appendix E of Volume 2 of this EIS. The environmental effects of implementing both the domestic and foreign portions of the policy can be obtained by adding the appropriate values from Volume 2 and values from this appendix.

C A.2 Case Description

The case description given in this section of the appendix provides information on process actions involving foreign fuel. These actions were developed from the expected actions that may be encountered under the U.S. Spent Fuel Storage Policy for the combined U.S. and foreign fuels. Only the foreign actions are listed in this appendix.

A.2.1 Policy Implemented

Under the "Policy Implemented" alternative with delay of startup of the first U.S. geologic repository until the year 2010, the U.S. offer to accept foreign spent fuel for storage is assumed to be implemented for the Option 2 fuel schedule. This case (called Case I) is the option preferred by DOE for the delayed startup of U.S. geologic facilities and is the same as Case G described in Section III.B.8 of this volume except that foreign spent fuel is stored in a U.S. ISFS facility for a longer period (until the geologic repository is available). A decision is also assumed to be made after the year 2010 to dispose of the foreign fuel stored in the U.S., along with U.S. spent fuel, in a U.S. geologic repository.

The foreign spent reactor fuel (about 4350 MTU) is assumed to be shipped to a U.S. ISFS facility starting in the year 1983. This foreign fuel is stored in the U.S. ISFS until the year 2019. Starting in the year 2019, foreign spent fuel is shipped to the U.S. geologic repository for disposal.

Nonproliferation benefits for Case I are the same as for Case G. The environmental effects from Case I are determined for the following activities:

- Shipment of about 4350 MTU spent fuel from foreign ports (for the years 1983 to 2000) and storage in the U.S. ISFS facility through the year 2030.

- Shipment to a U.S. geologic repository of about 4350 MTU foreign spent fuel from U.S. ISFS facilities for the years 2019 to 2030.

- Decommissioning of ISFS facilities in the years 2021 to 2032.

A.2.2 Policy Not Implemented

Under the "Policy Not Implemented" alternative with startup of the first U.S. geologic repository in the year 2010, it is assumed that the U.S. Government decides not to implement the U.S. Spent Fuel Storage Policy for foreign fuel and therefore would not accept spent fuel from foreign countries for interim storage. Foreign spent fuel is assumed to be reprocessed in foreign countries, the generated reprocessing waste disposed of in a foreign geologic repository and the recovered uranium and plutonium recycled as refabricated reactor fuel. The case (called Case J) is similar to Case A described in Section III.B.1 of this volume, but amounts of spent fuel for Case J are about one-third of that for Case A. Under this scenario reprocessing of spent fuel equivalent to the Option 2 foreign spent fuel schedule (4350 MTU) is considered.

Because foreign spent fuel does not enter the U.S. under Case J, there is no environmental effect to the U.S. and global commons from foreign spent fuel. However, if the U.S. does not accept foreign spent fuel for storage, the proliferation risks would be greater than with U.S. acceptance of foreign fuel.

The environmental effects from Case J were determined for the following activities:

- Transportation of 4350 MTU of foreign spent fuel from foreign reactor basins (for the years 1983 to 2001), and
- Cask receiving and venting at the FRP storage basin of the 4350 MTU of foreign fuel transported.

A.3 Summary of Environmental Impacts

The nonproliferation benefits for Case I (Policy Implemented) are the same as for Case G and are described in Sections III.B.8.1 and II.D.2 of this volume. This case assumes that the U.S. would decide, on a case-by-case basis, to receive foreign fuel from countries located in a sensitive region of the world where protracted storage of this spent fuel might be judged troublesome in terms of nonproliferation concerns and from a limited number of other countries where there is a nonproliferation benefit and the countries have no ready alternative solutions for spent fuel disposition from a nonproliferation standpoint. In Case J, these same countries are assumed to have the spent fuel reprocessed in national or multinational reprocessing facilities. Therefore, the proliferation risks from a U.S. perspective would be greater for Case J than for Case I, and Case I is the preferred option.

The environmental effects for Cases I and J on the U.S. and global commons and the world with startup of the first U.S. geologic repository in the year 2010 are summarized in Table A-1 for interim operations only. For Case I, all operations involving

C

TABLE A-1

Summary of Major Environmental Effects (Interim Operations)[a]

	Policy Implemented Foreign Fuel to U.S. Case I	*Policy Not Implemented* Foreign Fuel Reprocessed Abroad Case J
Population Whole Body Dose Commitment, man-rem		
U.S. and Global Commons	1400	0
World	1400	8.5
Occupational Whole Body Exposure, man-rem		
U.S. and Global Commons	330	0
World	360	43
Health Effects from Population Dose Commitment and Occupational Exposure[b]		
U.S. and Global Commons	1.0	0
World	1.1	0.04
Accidental Deaths		
U.S. and Global Commons	0.5	0
World	0.5	0.1

a. Option 2 Fuel Schedule.

b. Serious somatic and genetic 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 under this column along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

C the foreign spent fuel, except for maritime transportation and cask loading onto ships in the foreign countries are carried out in the U.S. Thus, the effects on the U.S. and global commons and on the world are the same except for those associated with loading spent fuel casks containing foreign spent fuel onto the ship, and this makes a slight contribution to the total (less than 10%). All of the effects from interim operations in Case J occur in foreign countries because this case assumes no foreign fuel is accepted in the U.S. Since the only interim action in Case J is the shipment from foreign reactors to foreign reprocessing plants, the environmental effects of these interim operations are quite small as can be seen from Table A-1. The environmental effects for Case I are also small when compared to the effects on the same population groups from natural background radiation sources and accidental deaths due to nonradiological accidents from other industrial activities.

A.4 Environmental Analyses

The major environmental impacts assessed in this appendix for Cases I and J are nonproliferation benefits, population dose commitments, occupational exposures, radiological health effects, and accidental deaths. Resources committed for Cases I and J were not calculated in this appendix. Resources for Case I are essentially the same as those given on Tables VI-2 and VI-4 for Case G. Case J resources committed should be about one-third of those given in Tables VI-2 and VI-4 for Case A.

The environmental impacts of nonradiological releases (e.g., thermal effluents, liquid and chemical effluents, etc.) are not included in this appendix. These effects were assessed in Volume 2 where they were noted to be well within accepted limits for handling, transport, and storage of 72,200 MTU of domestic spent fuel to ISFS facilities. The nonradiological effects of handling and storing 4350 MTU of foreign fuel are much less.

A.4.1 Methodology

The methodology used in calculating the environmental effects for the cases analyzed in this appendix is the same as that used in Volume 2 and is described in more detail in DOE-ET-0054.[5] Assumptions for release rates, transportation activities, injury rates, demography, etc. are the same as those in sections of the main body of this volume.

A.4.2 Environmental Impacts

This section discusses the nonproliferation and major environmental effects of implementing or not implementing the

C U.S. Spent Fuel Policy for foreign spent fuel with startup of the first U.S. geologic repository delayed until the year 2010.

A.4.2.1 Case I - Fuel Shipped to U.S. for Storage, Later Disposed of in U.S. Geologic Repository (Option 2 Fuel Schedule)

A.4.2.1.1 Effects of U.S. Nonproliferation Policy (Case I)

The nonproliferation effects for the Option 2 fuel schedule assumed for Case I are discussed in detail in Section II.D.2 of this volume. Under this option, the U.S. would accept spent fuel on a case-by-case basis from a limited number of countries where there is a nonproliferation benefit to the U.S. and those countries do not have ready alternative solutions for fuel disposition that are acceptable from a nonproliferation standpoint. These foreign countries would have assumed that reprocessing would take place and therefore would not have planned for interim or terminal geologic storage for their expected spent fuel. If some of their spent fuel is stored in the U.S., these foreign countries could forego premature reprocessing, may be able to obtain the time to explore regional or international cooperation for spent fuel storage, and could be encouraged to accept more extensive nonproliferation assurances and adherence to international nonproliferation treaties.

A.4.2.1.2 Other Major Environmental Effects (Case I)

The major environmental effects of Case I (other than effects on U.S. nonproliferation policy) are given in Tables A-2 and A-3, assuming startup of the first U.S. geologic repository in the year 2010. Table A-2 gives the effects on the U.S. and global commons, and Table A-3 gives the effects on the world. For Case I, where Option 2 foreign fuel is received in the U.S., the dose commitment to the U.S. and global commons population and the world total is 1400 man-rem. The occupational dose of 330 man-rem occurs in the U.S. and global commons and the world total occupational dose is 360 man-rem for the interim operations considered in Case I. The combined population and occupational doses result in about one health effect for this case. Less than one accidental death is predicted.

A.4.2.2 Case J — Fuel Reprocessed Abroad (Option 2 Fuel Schedule)

A.4.2.2.1 Nonproliferation Effects (Case J)

The nonproliferation effects for nonimplementation of the U.S. policy in regard to the foreign spent fuel, i.e., no interim

C TABLE A-2

Major Environmental Effects to the U.S. and Global Commons (for Interim Operations)[a]

Interim Operations	*Whole Body Commitment, man-rem* *Population*	*Occupational*	*Health Effects from Population and Occupational Exposures*[b]	*Accidental Deaths*
Policy Implemented — Spent Fuel to the U.S. for Storage and Disposal				
Transportation	10	54	0.04	0.2
ISFS and Cask Venting at Geologic Repository	1400	280	1.0	0.3
Total	1400	330	1.0	0.5
Policy Not Implemented — Spent Fuel to be Reprocessed Abroad				
Transportation	-[c]	-	-	-
Cask Receiving and Venting at FRP	-	-	-	-
Total	-	-	-	-

a. Option 2 Fuel Schedule.

b. Serious somatic and genetic 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 under this column along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

c. The dashes in the table indicate that the facility or operation indicated in the first column is not involved in the type of activity listed above the dash.

C

TABLE A-3

Major Environmental Effects for the World (for Interim Operations)[a]

Interim Operations	*Whole Body Commitment, man-rem*		*Health Effects from Population and Occupational Exposures*[b]	*Accidental Deaths*
	Population	*Occupational*		
Policy Implemented — Spent Fuel to the U.S. for Storage and Disposal				
Transportation	10	78	0.06	0.2
ISFS and Cask Venting at Geologic Repository	1400	280	1.0	0.3
Total	1400	360	1.1	0.5
Policy Not Implemented — Spent Fuel to be Reprocessed Abroad				
Transportation	6.5	18	0.02	0.1
Cask Receiving and Venting at FRP	2	25	0.02	0.001
Total	8.5	43	0.04	0.1

a. Option 2 Fuel Schedule.

b. Serious somatic and genetic 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 under this column along with those caused by the whole body dose. (See Appendix B of Volume 2 for more detail on methodology used in determining health effects.)

C storage of foreign spent fuel in the U.S., is discussed in Section III.B.1.1 of this volume for the Option 3 fuel schedule (Case A). The nonproliferation effects for Case J (no foreign fuel accepted in the U.S. - Option 2 fuel schedule) would be the same since in both of these cases all foreign fuel is reprocessed.

In the absence of a U.S. spent fuel storage offer, there will be some transportation of spent fuel among countries, either for storage or reprocessing of spent fuel. Transfers for reprocessing would also involve return shipments of waste and separated plutonium or mixed oxide fuel. It is believed that shipment of plutonium or unirradiated MOX fuel is easier to divert for use in construction of illicit nuclear devices than irradiated spent fuel and this case would, therefore, create a greater proliferation risk than for Case I. Accumulation of spent fuel at storage facilities also presents stocks of spent fuel that could be reprocessed to recover its contained plutonium.

If the U.S. does not accept foreign spent fuel for storage, the proliferation risks would be greater than the risks associated with the U.S. acceptance of foreign spent fuel. It is believed that if the U.S. offer is made, foreign spent fuel storage would be minimized, and some foreign reprocessing would be forestsalled. Thus, nuclear proliferation potential would be reduced. It is possible that other factors, including discussions in the International Nuclear Fuel Cycle Evaluation (INFCE), costs, physical security problems, national nonproliferation interests, or fuel cycle policies will induce nations currently interested in reprocessing to alternately choose to store their spent fuel. If this occurs and the U.S. has not made the offer for storage of foreign spent fuel, other nations may still be encouraged to build interim storage facilities or to negotiate bilaterial, multinational, or international storage arrangements. However, such an outcome could also mean that spent fuel would remain in sensitive regions. In the absence of reprocessing, spent fuel itself is not a weapons-usable material; however, its continued presence does mean that a reprocessing option remains available.

A.4.2.2.2 Other Major Environmental Effects (Case J)

The major environmental effects of Case J (other than effects on the U.S. nonproliferation policy) are given in Tables A-2 and A-3, assuming startup of the first U.S. geologic repository in the year 2010. Only the interim effects (transportation to the FRP and cask receipt and venting) are assessed for Option 2 fuel schedule in Case J. Table A-2 shows that there are no effects on the U.S. and global commons from interim operations of Case J. Table A-3 gives the effects on the world from these interim operations.

C For Case J, the interim operations considered in this assessment result in a population dose commitment of about 9 man-rem and an occupational dose of 43 man-rem which, when combined, result in much less than one radiological health effect. Less than one accidental death is projected for these interim operations.

C REFERENCES

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. Draft Environmental Impact Statement - Storage of Foreign Spent Power Reactor Fuel, USDOE Report DOE/EIS-0040-D, U.S. Department of Energy, Washington, DC (December, 1978).

3. The President's Program on Radioactive Waste Management, A Report to Congress by the President of the United States, The White House, Washington, DC (February 12, 1980).

4. NRC Rulemaking on Nuclear Waste Storage and Disposal, Department of Energy Statement of Position, U.S. Department of Energy, Washington, DC (April 15, 1980).

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

APPENDIX B - 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 occurring 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).

AFR

An acronym for away-from-reactor. Sometimes used as AFR basins.

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.

C ARB

At-reactor basin. A facility constructed adjacent to reactors to provide interim storage of spent fuel while minimizing risks to the public associated with transporation.

background dose

The levels of ionizing radiation received in man's natural environment, including cosmic rays and radiation from naturally occurring radioactive elements.

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 (H_2O) is used as the coolant.

CANDU

CANada Deuterium Uranium reactor is a nuclear reactor in which natural uranium is used as fuel. It is heavy-water (D_2O) moderated, reflected, and cooled.

canister

A metal container for radioactive solid waste.

cask

A container that provides shielding and containment for the shipment or storage of radioactive material.

cc

Cubic centimeters

C cfm

Cubic feet per minute

CFR

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)

U.S. Code of Federal Regulations Title 10. Part 100, Reactor Site Criteria.

C | Category 1 Structure

A structure designed to withstand maximum credible natural disasters, such as earthquakes or tornadoes.

Ci

C | Curie(s) (see "curie")

cladding

The outer jacket of a nuclear fuel or target element.

cladding waste

Cladding waste consists of hulls, other hardware components, and residual fines which remain after spent fuel is dissolved in a reprocessing plant. Cladding waste is mostly Zircaloy, Inconel,* and stainless steel. The components contain activation products and some residual radionuclides. Sometimes referred to as fuel residue wastes.

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.

C | 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 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 of radioactivity in a sample of material. One curie (Ci) equals 37 billion disintegrations per second.

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* Trademark of Huntington Alloys, Inc.

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 facilities from service and reduce or stabilize radioactive contamination.

decontamination

The selective removal of radioactive material from a surface or from within another material.

densification

See "compaction."

depleted uranium

Uranium having a percentage of uranium-235 smaller than the 0.7% found in natural uranium.

discharge capability

C Reserve storage capacity maintained in a reactor 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 because no provision is made for recovery.

disposition facility

An undefined generic facility assumed, in this volume, to receive spent fuel from reactor and ISFS facilities, or reprocessing waste from an FRP at some point in the schedule.

DOE

Department of Energy (created October 1, 1977). Includes former Energy Research and Development Administration which was created January 19, 1975, when the Atomic Energy Commission was abolished.

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 dose 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 facility to be used for the storage and disposal of nuclear waste.

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.

frequency

The number of times an event can be postulated to occur, or actually occurs per unit of time.

FRP

Abbreviation for fuel reprocessing plant.

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 (nuclear)

The complete series of steps involved in supplying fuel for nuclear reactors. The cycle includes uranium 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 irradiated uranium and refabrication into new fuel elements.

fuel element

The smallest structurally discrete part of a reactor assembly which has nuclear fuel as its principal constituent.

full-core reserve

C Reserve storage capacity maintained in a reactor discharge basin to accommodate all 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, return on invested capital, and 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)

Short-wave length 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.

global commons effects

See U.S. and global commons effects.

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 statement, a health effect from exposure to ionizing radiation may be a somatic effect (malignancy) and/or a genetic effect. Somatic and genetic effects are summed to show total health effects.

heavy water

Deuterium oxide, D_2O. Water in which hydrogen atoms have been replaced with deuterium atoms.

heavy water reactor

Uses heavy water (D_2O) as moderator for slowing fast neutrons. May use light or heavy water for coolant.

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 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.

high-level waste (HLW)

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 disposed of without processing.

IAEA

International Atomic Energy Agency.

ICRP

International Commission on Radiological Protection.

interim storage

Storage operations for which (a) surveillance and human control are provided and (b) subsequent action involving treatment, transportation, or fuel disposition is expected.

intermediate-level liquid waste (ILLW)

The aqueous waste, other than high-level liquid and cladding waste, from reprocessing plants that require shielding or other protective actions during handling. This includes aqueous wastes from extraction cycle evaporator overhead and miscellaneous waste solutions.

intermediate-level waste (ILW)

Intermediate-level liquid waste or products from solidification of intermediate-level liquid waste obtained from chemical processing of irradiated fuel.

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).

kw-hr

Kilowatt-hour. A unit of energy generation or comsumption in a given hour.

kWh

A contracted form of kW-hr.

kW-yr

Kilowatt-year. A unit of energy generation or consumption in a given year.

kWyr

A contracted form of kW-yr.

lattice

The geometric arrangement of fuel assemblies.

light water

Normal water (H_20), as distinguished from heavy water (D_20).

light water reactor (LWR)

Uses light water (H_20) 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.

low-level liquid waste (LLLW)

The aqueous waste generated at plants handling radionuclides that are low in radionuclide content and do not require significant shielding. The concentrated low-level waste is recycled into intermediate-level waste.

low-level waste (LLW)

Low-level solid waste is miscellaneous solid waste materials that contain beta-gamma emitters and traces of TRU alpha emitters in concentrations <10 nCi/g. This waste is normally made up of ash from incinerated combustible wastes, decontaminated equipment, etc. This waste is normally sent to a burial ground for disposal.

low-level transuranic waste (LLW-TRU)

LLW-TRU is miscellaneous solid waste materials that contain beta-gamma emitters and transuranic radionuclides with TRU alpha emitters in concentrations >10 nCi/g. This waste requires long-term storage or disposal in a geologic repository.

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.

maritime

On or by sea.

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 kilograms (1 Tonne).

mg

milligrams.

C micro (μ)

Prefix indicating 10^{-6} times the affixed unit, abbreviated "μ" milli

Prefix indicating one-thousandth (1 millirem = 1/1000 of a rem or 10^{-3} rem).

millirem

One-thousandth of a rem.

mixed oxide fuel

Nuclear fuel containing oxides of uranium and plutonium.

mL

milliliter(s)

C MM

Modified Mercalli (scale of earthquake intensity).

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.

mrem

millirem

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 (0.7%), and a minute percentage of uranium-234.

nCi

nanocurie(s).

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.

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 administrative 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 the 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 protective packaging for packaged nuclear waste.

OWT

Abbreviation for overweight truck.

pCi

pico-curie(s).

pico

Prefix indicating one-millionth of a micro unit (1 picocurie = 1/1,000,000 of a microcurie or 10^{-12} curie).

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 members of a population group over a given time period.

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 emmission 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.

RBOF

Receiving Basin for Offsite Fuels, a facility at the DOE's Savannah River Plant.

reactor (nuclear)

A device in which a fission chain reaction can be initiated, maintained, and controlled.

regional effects

The effects on nine million km^2 that result from foreign operations at the center of that land area (assumed for this volume).

rem

A unit used in radiation protection to express the effective dose equivalent for all forms of ionizing radiation. It is
C the product of the absorbed dose in rads, quality factors, 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 and recovery of useful materials such as thorium, uranium, and plutonium. Other radioactive materials are usually separated and treated as waste.

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.

roentgen

A unit of exposure of ionizing radiation. It is a measure 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.

sensitive facilities

Facilities capable of producing material usable in nuclear explosive devices.

sensitive materials

1) Fissionable materials that can be used to construct nuclear weapons or 2) radioactive materials that might be dispersed by saboteurs or malevolent groups.

sensitive regions

Areas in the world in which international tensions are high and a risk of violent conflict may occur.

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).

spent fuel

Irradiated nuclear reactor fuel at the end of its useful life.

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.

ton

C | Unit of weight, 1 ton = 2000 pounds (1 short ton).

tonne

C | Unit of weight, 1 tonne = 1000 kg (1 metric ton).

transurantum 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: neptunium, plutonium, curium, californium.

transuranic waste

Any 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 natural 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).

U.S. and global commons effects

In this EIS, total world effects less those associated with regional effects that result from operations in foreign countries.

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.

μ

Prefix indicating one millionth. Same as "micro."

C

Summary of Operations Involved in Cases

Case	*A*[a]		*B*[a]		*C*[a]		*D*	*E*	*F-1*	*F-2*	*G*	*H*	*I*	*J*
Foreign Spent Fuel Fuel Schedule Option[b]	3		3		3		3	3	3	3	2	1	2	2
Retained in Foreign Countries	●	●	●	●	●	●								●
Interim Storage in Foreign Countries Without U.S. Support	●	●												●
U.S. Supports Interim Storage in Countries of Origin Except Those Located in Sensitive Regions					●	●								
U.S. Supports Interim Storage in Multinational Storage Facilities Located in Countries Outside Sensitive Regions			●	●										
Spent Fuel Disposed of as Waste in Foreign Geologic Repositories		●		●		●								
Reprocessed in Foreign Countries[c]	●		●		●									●
Separated Plutonium and Uranium Recycled in Foreign Countries	●		●		●									●
Shipped to U.S. for Storage							●	●	●	●	●	●	●	
Returned to Foreign Countries								●						
Reprocessed in U.S.[d]									●	●				
Returned to Foreign Countries and Reprocessed[c]								●						
Separated Plutonium and Uranium Recycled in U.S.									●					
Separated Plutonium and Uranium Recycled in Foreign Countries								●		●				
Disposed of as Waste in U.S. Geologic Repository — Repository Startup Date 1985							●				●	●		
Disposed of as Waste in U.S. Geologic Repository — Repository Startup Date 1995							●				●	●		
Disposed of as Waste in U.S. Geologic Repository — Repository Startup Date 2010													●	

a. In Cases A, B, and C, disposition of the spent fuel by reprocessing and by disposal in a geologic repository is considered. In the first column, the fuel is assumed to be reprocessed. In the second column, the spent fuel is assumed to be disposed of as waste in a geologic repository.

b. As detailed in Section II-D, three different levels of foreign spent fuel (Options 1, 2, and 3) are identified in this study of the U.S. offer to store foreign spent fuel.

The Option 1 foreign spent fuel schedule includes fuel from countries inside sensitive regions. Acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

The Option 2 foreign spent fuel schedule includes the Option 1 fuel level and in addition, acceptance of spent fuel from a limited number of other countries with spent fuel storage problems (from a nonproliferation standpoint). Acceptance of fuel by the U.S. will be considered on a case-by-case basis.

The Option 3 foreign spent fuel schedule includes the Option 2 fuel level and in addition, acceptance of some of the spent fuel from a larger number of non-nuclear-weapons states. Again, acceptance of fuel from these countries will be considered from the standpoint of U.S. nonproliferation objectives on a case-by-case basis.

c. Reprocessing waste is disposed of in foreign geologic repositories.

d. Reprocessing waste is disposed of in U.S. geologic repository.