**ENVIRONMENTAL ASSESSMENT
FOR THE PURCHASE OF
RUSSIAN LOW ENRICHED URANIUM
DERIVED FROM THE DISMANTLEMENT
OF NUCLEAR WEAPONS IN THE
COUNTRIES OF THE FORMER SOVIET UNION**

JANUARY 1994

USEC

**U.S. ENRICHMENT CORPORATION
Bethesda, Maryland**

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MASTER

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LIST OF ACRONYMS AND ABBREVIATIONS

<u>ACRONYM</u>	<u>WORD</u>
ACGIH	American Conference of Governmental Industrial Hygienists
AEC	Atomic Energy Commission
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing Materials
AVLIS	Atomic Vapor Laser Isotope Separation
CEQ	Council on Environmental Quality
CERL	Construction Engineering Research Laboratory
CIS	Commonwealth of Independent States
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EA	Environmental Assessment
EC	European Community
EEI	Electric Energy, Incorporated
EIA	U.S. Energy Information Administration
EO	Executive Order
EPA	U.S. Environmental Protection Agency
FOB	Freight on Board
GDP	Gaseous Diffusion Plant
HEU	Highly Enriched Uranium
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IDLH	Immediately Dangerous to Life or Health
LCF	Latent Cancer Fatality
LEU	Low Enriched Uranium
LLNL	Lawrence Livermore National Laboratory
LWR	Light Water Reactor
NEPA	National Environmental Policy Act
NCRP	National Committee on Radiation Protection and Measurements
NID	Negligible Individual Dose
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Act
OVEC	Ohio Valley Electric Company
SWU	Separative Work Unit
TI	Transport Index
TLV	Threshold Limit Values
USEC	United States Enrichment Corporation

CHEMICAL SYMBOLS AND FORMULAS

ABBREVIATION

HF
U-234
U-235
U-238
UF₆
UO₂
UO₂F₂
U₃O₈

WORD

hydrogen fluoride
uranium isotope 234
uranium isotope 235
uranium isotope 238
uranium hexafluoride
uranium dioxide
uranyl fluoride
uranium oxide (yellowcake)

UNITS OF MEASURE

ABBREVIATION

Bq
C
Ci
F
in.
kg
km
mi
mrem
mSv
MSWU
MTU
MWe
psia
SWU
t

WORD

becquerel
Celsius
curie
Fahrenheit
inch
kilogram
kilometer
miles
millirem
millisievert
million separative work unit
metric tons uranium
megawatts of electricity
pounds per square inch, absolute
separative work unit
tonne (1t = 1,000 kg)

EXECUTIVE SUMMARY

BACKGROUND

The United States is proposing to purchase from the Russian Federation low enriched uranium (LEU) derived from highly enriched uranium (HEU) resulting from the dismantlement of nuclear weapons in the countries of the former Soviet Union. The purchase would be accomplished through a proposed contract requiring the United States to purchase 15,250 metric tons (tonnes) of LEU (or 22,550 tonnes of UF_6) derived from blending 500 metric tonnes uranium (MTU) of HEU from nuclear warheads. The LEU would be in the form of uranium hexafluoride (UF_6) and would be converted from HEU in Russia.

The contract would further the goals of various arms control agreements between the two nations, including the Treaty on the Nonproliferation of Nuclear Weapons and would be entered into pursuant to a government-to-government agreement to arrange for safe and prompt disposition for peaceful purposes of HEU extracted from dismantling the former Soviet Union's nuclear arsenal. In addition, the two countries must agree on the details and the procedure for transparency, which includes the process of permitting the United States to gain confidence that the HEU is actually derived from dismantled nuclear weapons, and that the HEU is blended to LEU.

The United States Enrichment Corporation (USEC) is the entity proposing to undertake the contract for purchase, sale, and delivery of the LEU from the Russian Federation. The U.S. Department of Energy (DOE) is negotiating the procedure for gaining confidence that the LEU is derived from HEU that is derived from dismantled nuclear weapons (referred to as "transparency"), and would administer the transparency measures for the contract.

An estimated 500 MTU of HEU converted to LEU would be purchased over a 20-year period beginning in fiscal year 1994 (FY94) and ending in fiscal year 2013 (FY13). The assay of LEU produced in Russia would be expected to be 3 to 5 percent uranium-235 (U-235). In total, an estimated 15,250 MTU of LEU or 22,550 metric tons (tonnes) of UF_6 would be transported to the United States from Russia in containerized cargo packages called SEAPAKs. Each SEAPAK would contain about 9 tonnes of UF_6 loaded in four standard commercial steel model 30B cylinders. The LEU would be sold by the USEC for ultimate use as commercial nuclear reactor fuel.

The proposed purchase would fulfill multiple needs and purposes, including:

- Promoting the safe and prompt disposition for peaceful purposes of HEU resulting from dismantlement of nuclear warheads in Russia.
- Furthering the objectives of the Treaty on the Non-Proliferation of Nuclear Weapons.

- Affirming the commitment of the United States and the Russian Federation that nuclear materials transferred for peaceful purposes under the agreement comply with all applicable non-proliferation, material accountability and control, physical protection, and environmental requirements.
- Providing funds to the Russian Federation for the conversion of defense enterprises, enhancing the safety of nuclear power plants, environmental clean-up of polluted areas and the construction and operation of facilities in the Russian Federation for the conversion of HEU to LEU.
- Promoting economic reforms in the Russian Federation and the transition to a market-based economy.

PROPOSED ACTION

The proposed action consists of six principal elements:

1. Signing of a contract for purchase, sale, and delivery of LEU.
2. Negotiation and agreement on detailed procedures for transparency to gain confidence that LEU is derived from HEU that is derived from dismantled nuclear weapons.
3. Determination that the HEU extracted from nuclear weapons pursuant to the Agreement is oxidized, fluorinated, and subsequently blended with natural uranium or LEU blendstock to yield LEU end-product enriched to less than 5 percent U-235.
4. Shipment of the LEU from St. Petersburg, Russia, via the Gulf of Finland, Baltic Sea, North Sea, and Atlantic Ocean to one or more of seven proposed ports of entry (Port of Hampton Roads, Virginia; Port of Baltimore, Maryland; Port of Philadelphia and South New Jersey, Pennsylvania and New Jersey; Port of New York and New Jersey, New York and New Jersey; Port of Houston, Texas; Port of Charleston, South Carolina; and Port of Savannah, Georgia) by commercial ocean freighter.
5. Transport of the LEU by commercial truck from the port of entry to the Portsmouth GDP.
6. Placement of the LEU in the GDP inventory where it would be made available to USEC utility customers to be fabricated into fuel as orders are received.

ALTERNATIVES

The following alternatives to the proposed action are assessed in this environmental assessment (EA).

1. No Action. The no action alternative maintains the status quo by not purchasing the Russian LEU.
2. Receipt at the Paducah GDP. Under this alternative, the UF₆ would be transported in part, or in total, to the Paducah GDP at Paducah, Kentucky, instead of solely to the Portsmouth GDP.

3. Receipt at Fuel Fabricators, Domestic or Abroad. The shipment of LEU from Russia or the U.S. port of entry directly to a fuel fabricator would result in the USEC acting as a broker in the shipment of LEU since no material would be shipped to or processed at the Portsmouth GDP.
4. Optional Transport Mode to the United States. Under this alternative, the UF_6 would be transported from Russia to the U.S. by means of military or commercial aircraft.
5. Transportation of LEU from Several Alternative Ports of Entry. Several low, medium, and high population density ports of entry are considered as alternatives.
6. Transport of LEU within the United States by Rail. With respect to the rail alternative, each rail car could hold four Model 30B cylinders of LEU in their SEAPAKs, the same as a commercial truck. However, a number of rail cars could be accommodated in any one train. For purposes of this analysis, it was reasonable to assume that for each shipment 32 Model 30B cylinders would be transported in eight rail cars of the same train.

ENVIRONMENTAL IMPACTS

The six environments that could potentially be affected by the proposed action are marine (ocean), U.S. ports of entry, truck or rail transportation corridors, the Portsmouth GDP, the electric power industry, and the nuclear fuel cycle industry.

Ocean transport would be from St. Petersburg, Russia, to one or more of seven proposed ports of entry (Port of Hampton Roads, Virginia; Port of Baltimore, Maryland; Port of Philadelphia and South New Jersey, Pennsylvania and New Jersey; Port of New York and New Jersey, New York and New Jersey; Port of Houston, Texas; Port of Charleston, South Carolina; and Port of Savannah, Georgia). From there the UF_6 would be transported by commercial truck to the Portsmouth GDP. The plant has been in operation as a uranium enrichment facility since the mid-1950s.

The effects of ocean and land transportation of Russian LEU are analyzed through use of a computer code known as RADTRAN 4. LEU transportation health and safety issues are addressed and include a detailed discussion of the transportation risk analysis methodology used in this EA. Radiological and chemical exposures and health effects under both routine conditions and transportation accident scenarios are analyzed. The calculated maximum annual radiation exposure to a member of the general public for incident-free transportation is estimated as 0.002 millirem (mrem), which is 50,000 times less than the U.S. Nuclear Regulatory Commission (NRC) allowable annual dose of 100 mrem.

UF_6 has been transported safely around the world by air, water, and land for more than 30 years. In all that time, there has never been an accident during transport involving the release of UF_6 from an accident-resistant package with overpack. In fact, there has not been a transportation accident in the last 30 years that has resulted in fatalities or injuries due to the chemical or radioactive nature of UF_6 . In the last ten years (1984-1993), 16311 shipments of UF_6 (94,360 metric tons uranium) were safely shipped

within the United States. Approximately 650,000 metric tons of UF_6 have been safely shipped to and from the Portsmouth GDP since the beginning of its operation in the mid-1950s through March, 1993.

UF_6 is regularly transported as a solid material in large steel cylinders by train, truck, and ship. These cylinders typically can hold 2 1/2, 10, or 14 tons of UF_6 . Commercial trucks routinely transport UF_6 between facilities in the United States and to various U.S. ports for shipment overseas. In addition, UF_6 is routinely transported into the United States. No special permits or applications are required to transport UF_6 by train, truck, or ship. The U.S. Department of Transportation's (DOT's) regulations treat UF_6 of the type involved here (enriched to less than 20 percent U-235) as presenting a sufficiently minimal hazard that an "unlimited" quantity of uranium can be shipped in specified packaging, referred to as Type A packaging [DOT, 1990].

The shipment of enriched UF_6 in Model 30B cylinders in overpacks has been incident-free with respect to releases of radioactive material. As a result, no direct experience base exists for establishing the consequences of transportation accidents. However, for purposes of assessing potential environmental impacts of an overland transportation accident, a severe accident leading to the total release of the UF_6 contained in four 30B cylinders in their overpacks, at 4.4 percent U-235, was analyzed. A severe accident of this type is extremely unlikely to occur. Nevertheless, as part of the analysis, this extremely low-probability severe accident is discussed in this EA. Individuals within 350 feet of such a release could inhale potentially lethal doses of hydrogen fluoride if present for exposure to the entire plume of released material. The probability of such a release occurring is estimated as 0.000000065 (6.5×10^{-8}), or 6.5 chances out of one hundred million, for the entire 20 years of the proposed action, using Hampton Roads as the port of entry for example purposes. The estimated maximum total latent cancer fatality (LCF)¹ risk resulting from both incident-free transportation and potential accidents for the entire 20-year LEU purchase program ranges between 0.024 and 0.033, depending on the port of entry.

Incremental impacts on the environment surrounding the Portsmouth GDP resulting from a change in plant operations due to the purchase of Russian LEU are assessed and predicted to be minimal. Incremental impacts on the economic status of the communities surrounding the Portsmouth and Paducah GDPs are briefly discussed in that the Russian LEU would involve sufficient enriched uranium that it might become economically attractive to close one of the GDPs unless the anticipated increase in the market demand for USEC-enriched uranium occurs. Economic consequences in terms of impacts on nuclear fuel cycle markets and industries and the ports of entry are also discussed and estimated to be minimal. A comparison of the environmental consequences of the proposed action and the alternatives is presented.

¹ A latent cancer fatality is defined as a fatal malignancy that may occur after some latent period, usually 10 or more years, and has a probability of occurrence that increases with dose.

SECTION 1.0

PURPOSE AND NEED FOR ACTION

1.0 PURPOSE AND NEED FOR ACTION

The United States is proposing to purchase from the Russian Federation low enriched uranium (LEU) derived from highly enriched uranium (HEU) resulting from the dismantlement of nuclear weapons in the countries of the former Soviet Union. The purchase would be accomplished through a proposed contract requiring the United States to purchase 15,250 metric tons (tonnes) of LEU (or 22,550 tonnes of UF_6) derived from blending 500 MTU of HEU from nuclear warheads. The LEU would be in the form of uranium hexafluoride (UF_6) and would be converted from HEU in Russia. Under the proposed contract, LEU would be purchased beginning in fiscal year 1994 (FY94) and would continue to be purchased through fiscal year 2013 (FY13).

The contract would further the goals of various arms control agreements between the two nations, including the Treaty on the Nonproliferation of Nuclear Weapons, and would be entered into pursuant to a government-to-government agreement to arrange for safe and prompt disposition for peaceful purposes of HEU extracted from dismantling the former Soviet Union's nuclear arsenal. In addition, the two countries must agree on the details and the procedure for transparency, which includes the process of permitting the United States to gain confidence that the LEU is derived from HEU that is derived from dismantled nuclear weapons.

The United States Enrichment Corporation (USEC) is the entity proposing to undertake the contract for purchase, sale, and delivery of the LEU from the Russian Federation. The U.S. Department of Energy (DOE) is negotiating the procedure for gaining confidence that the LEU is derived from HEU that is derived from dismantled nuclear weapons (referred to as "transparency"), and would administer the transparency measures for the proposed contract.

The LEU purchase agreement would fulfill multiple purposes and needs including:

- Promoting the safe and prompt disposition for peaceful purposes of HEU resulting from dismantlement of nuclear warheads in Russia.
- Promoting the development and use of nuclear energy for peaceful purposes under arrangements that further the objectives of the Treaty on the Non-Proliferation of Nuclear Weapons of July 1, 1968.
- Affirming the commitment of the United States and the Russian Federation to assure that nuclear materials transferred for peaceful purposes under the Agreement comply with all applicable non-proliferation, material accountability and control, physical protection, and environmental requirements.
- Providing funds to the Russian Federation for the conversion of defense enterprises, enhancing the safety of nuclear power plants, environmental clean-up of polluted areas, and the construction and operation of facilities in the Russian Federation for the conversion of HEU to LEU.

- Promoting economic reforms in the Russian Federation and the transition to a market-based economy.

On October 24, 1992, President Bush signed the Energy Policy Act of 1992 (P.L. 102-486) which, among other things, established the USEC. Under amendments to the Atomic Energy Act of 1954, effected by the enactment of P.L. 102-486, the USEC will function as a wholly-owned government corporation authorized, among other duties, to purchase LEU derived from HEU from any state of the former Soviet Union. Thus, a corollary purpose of the proposed action is to implement a part of the national energy policy established by Congress.

The analysis contained herein has been prepared in consideration of the National Environmental Policy Act (NEPA), insofar as it addresses potential environmental impacts within the United States and in consideration of Executive Order 12114, insofar as it addresses extraterritorial impacts.

SECTION 2.0

**DESCRIPTION OF PROPOSED ACTION
AND ALTERNATIVES**

2.0 DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

The United States and the Russian Federation have agreed to reduce nuclear weapons stockpiles in accordance with various arms control agreements between the two nations, including the Treaty on the Nonproliferation of Nuclear Weapons. In addition, the United States and the Russian Federation have also entered into a government-to-government agreement to arrange for safe and prompt disposition for peaceful purposes of HEU extracted from dismantling the former Soviet Union's nuclear arsenal.

To advance the ultimate goals of these arms reductions agreements and pursuant to the government-to-government agreement, the United States is now proposing to purchase from the Russian Federation LEU derived from HEU resulting from the dismantlement of nuclear weapons in the countries of the former Soviet Union. The purchase would be accomplished through a proposed contract requiring the United States to purchase 15,250 metric tons (tonnes) of LEU (or 22,550 tonnes of UF_6) derived from blending 500 MTU of HEU from nuclear warheads. Payment for and delivery of the LEU would take place over a 20-year term beginning in FY94.

In the course of ongoing negotiations between the United States and the Russian Federation, the two governments have negotiated basic principles for the sale of such LEU, contingent upon a number of conditions. One such condition is the right of both countries to complete their respective governmental approval procedures for the proposed contract, which would include analysis of potential environmental impacts. In addition, the two countries must agree on the details of and the procedure for transparency, which refers to the process of permitting the United States to gain confidence that the LEU is derived from HEU that is derived from dismantled nuclear weapons.

DOE originally undertook the lead for the negotiations on behalf of the United States. However, Title IX of the Energy Policy Act of 1992 established the USEC and transferred many of the uranium enrichment functions from DOE to USEC, effective July 1, 1993. (Pub. L. No. 102-486, 106 Stat. 2923.) The Energy Policy Act authorizes USEC to negotiate the purchase of uranium from any nation of the former Soviet Union under a government-to-government agreement. (42 U.S.C. 2297c-7.) Accordingly, USEC is the entity proposing to undertake the contract for purchase, sale, and delivery of the LEU from the Russian Federation. However, DOE would administer transparency measures for the contract. Accordingly, DOE is negotiating the procedure for gaining confidence that the LEU derived from HEU is derived from dismantled nuclear weapons.

The LEU proposed to be purchased would be in the form of UF_6 with a concentration (referred to as the assay) of uranium-235 (U-235) ranging from 3 to 5 weight percent. The LEU purchased by the USEC would be derived from an estimated 500 metric tons of HEU metal with an average assay value of about 90 percent U-235. Dismantlement of nuclear warheads in Russia would provide the HEU used in the

conversion and blending process. The HEU would be converted to UF₆ and blended to produce low enriched UF₆ in the Russian Federation, which would then be shipped to the United States.

The assay of LEU produced in the Russian Federation would be less than 5 percent U-235 and would be expected to average about 4.4 percent U-235. It is assumed that the assay of the Russian HEU would be about 90 percent U-235 and that the HEU, once converted to UF₆, would be blended with 1.5 percent U-235 assay UF₆ to produce 4.4 percent U-235 LEU in UF₆ form for shipment. Under this set of assumptions, 10 metric tons of HEU, when blended and converted, would produce 451 metric tons of UF₆ at 4.4 percent U-235 assay. The 451 metric tons of UF₆ would contain approximately 305 metric tons uranium (MTU) and 146 metric tons of fluorine. (MTU will be used in this environmental assessment (EA) to quantify only the amount of uranium contained in a material and metric tons or tonnes (t) will be used when referring to the total mass of material.)

The Russian LEU would be shipped by commercial ocean freighter as UF₆ to the United States. Depending on when the contract would be signed, the LEU would be expected to be received in the United States according to the schedule shown in Table 2-1. It should be emphasized that only low enriched UF₆ would be received in the U.S.; the quantities of HEU are listed to provide comparative values of material.

Table 2-1. LEU Receipt Schedule

Material	FY94...FY98	FY99...FY13
HEU (MTU/yr)	10	30
LEU (MTU/yr)	305	915
UF ₆ (t/yr)	451	1,353

The receipt schedule indicates a total of 15,250 MTU of LEU or 22,550 tonnes of UF₆ to be shipped over a 20-year period. However, it is possible that one MTU of the proposed 500 MTU of HEU converted to LEU would be separately shipped, as an initial demonstration project for this proposed action.

The LEU would be shipped as UF₆ by commercial ocean freighter from St. Petersburg, Russia, via the Gulf of Finland, the Baltic Sea, the North Sea, and the Atlantic Ocean to one or more of seven proposed ports of entry (Port of Hampton Roads, Virginia; Port of Baltimore, Maryland; Port of Philadelphia and South New Jersey, Pennsylvania and New Jersey; Port of New York and New Jersey, New York and New Jersey; Port of Houston, Texas; Port of Charleston, South Carolina; and Port of Savannah, Georgia). The list of proposed ports was developed after a series of efforts were carried out to determine

the likely routes shipping companies would use to transport cargo from St. Petersburg to the United States. To develop a picture of how shipments would be transported between St. Petersburg and the United States, shipping schedules of major shipping lines, as published in "Shipcards" by the *Journal of Commerce*, were analyzed to determine the routes of vessels on regularly scheduled liner service. USEC restricted the search to vessels on regular liner service since these vessels tend to be higher quality in both vessel integrity and crew performance and, as a result, have a much lower casualty rate than vessels operating in the tramp (unscheduled) market. Sixteen shipping companies that advertise service to St. Petersburg, Russia, were also contacted by telephone to determine the ports in the United States at which their vessels called. Contact was also made with the U.S. Maritime Administration to verify the information obtained from the *Journal of Commerce* and the shipping companies. Finally, the Piers Import/Export data base was queried to determine where shipments of radioactive materials, particularly uranium hexafluoride, have been imported into the United States in the past several years. The information obtained from this research indicated that cargo originating in St. Petersburg would most likely be either initially or eventually shipped on vessels that make port calls at one or more of the seven ports proposed as potential ports of entry. From the port of entry, the UF_6 would be transported by commercial truck to the USEC- leased gaseous diffusion plant (GDP) at Piketon, Ohio. There, it would be placed in inventory and made available to the commercial nuclear power reactor fuel market. Consistent with the Energy Policy Act of 1992, the USEC is now operating the Portsmouth GDP at Piketon, Ohio, which DOE formerly operated and still owns.

All shipments to the United States would adhere to both United States and international regulations and standards pertaining to the preparation, packaging, handling, safeguards, transport, and receipt of radioactive materials. These would be implemented, as appropriate, according to requirements of the U.S. Department of Transportation (DOT), the U.S. Nuclear Regulatory Commission (NRC), the DOE or the USEC, and the International Atomic Energy Agency (IAEA).

2.1 PROPOSED ACTION

The principal components of the proposed action and their approximate sequence are as follows:

- Complete negotiation on contract terms and transparency procedures, and sign contract for purchase, sale, and delivery of LEU.
- Determination of HEU Conversion. The first access to Russian HEU by the United States would occur as a result of DOE implementing transparency inspections. The purpose of the monitoring procedures is to gain confidence that the HEU metal has been derived from dismantled nuclear weapons and that the LEU has been produced from blended HEU. DOE proposes to gain access to the HEU metal feed to the Russian oxidation facility, HEU hexafluoride feed to the blending facility, the LEU hexafluoride blend stock feed to the blending facility, and the LEU product stream from the blending facility. DOE proposes to witness the taking of samples of the HEU metal, the HEU hexafluoride and the LEU hexafluoride blend stock, and to have the option to ship

some or all of the samples to the U.S. for analysis. DOE would have access to all facilities used to carry out the terms of the agreement (see Section 4.0.).

- Sampling to Meet LEU Specifications. The first access to Russian LEU by the USEC would occur at the product transfer facility at the enrichment plant located near Yekaterinburg, Russia, where the USEC would have the right to inspect the LEU to ensure that it was properly packaged for shipment to the United States. In addition, the USEC, or its designated representative, would have the right to witness the taking of samples to ensure that the LEU met U.S. quantity, isotopic, and chemical specifications. If the USEC would elect not to send a witness to the Yekaterinburg plant, the Russian operators of the plant would take the samples for the USEC. These samples would be shipped by air express from the Russian plant in Yekaterinburg to the Portsmouth GDP at Piketon, Ohio. The samples would contain less than 450 grams of UF_6 and would be placed in DOT Specification 1S Sample Cylinders. (See Title 49, Code of Federal Regulations, Part 173.420.) For shipment, the Model 1S cylinders would be packaged in DOT Specification 17C Drums. (See Title 49, Code of Federal Regulations, Part 178.115.) The UF_6 samples in the 1S Sample Cylinders would contain less than 15 grams of the isotope U-235. A shipping package containing less than 15 grams of U-235 is exempt from regulations applying specifically to fissile material. (See Title 49, Code of Federal Regulations, Part 173.453(a); Title 10, Code of Federal Regulations, Part 71.53(a); and International Atomic Energy Agency Safety Series No. 6, "Regulations for the Safe Transport of Radioactive Material," 1985 Edition, As amended 1990, Section 560(a).)
- LEU Shipping Containers. The conversion/blending facilities in Russia would load the LEU into DOT Model 30B cylinders provided by the USEC (see Section 6.2 for a description of these containers). DOT Model 30B cylinders have been approved for international and domestic shipments of UF_6 . Each cylinder would hold about 2.28 tonnes (2,280 kilograms) of UF_6 consisting of approximately 1.5 MTU and approximately 0.8 tonnes of fluorine. All cylinders would be packaged in specification number 21PF-1B protective overpacks. (See Section 6.2 for a description of these overpacks). The overpacks would not be opened from the time they were loaded with 30B cylinders filled with LEU in Russia until they were delivered to the Portsmouth GDP in the United States. Tamper indicating devices would be attached at the Yekaterinburg plant to the valve and plug of each 30B cylinder and the 21PF-1B overpacks to provide assurance that overpacks and cylinders are not opened. The 21PF-1B overpacks containing the 30B cylinders would be loaded into specially designed 8 feet by 8 feet by 20 feet shipping containers called SEAPAKs for transport to the United States.
- Transfer of LEU to the United States at St. Petersburg, Russia. The United States would take possession freight on board (FOB) of the LEU at St. Petersburg where the integrity of the packages would be confirmed by U.S. representatives by visual inspection of the overpack and attached tamper indication devices.
- Shipment of LEU to the U.S. The LEU would be shipped to one or more of seven proposed ports of entry (Port of Hampton Roads, Virginia; Port of Baltimore, Maryland; Port of Philadelphia and South New Jersey, Pennsylvania and New Jersey; Port of New York and New Jersey, New York and New Jersey; Port of Houston, Texas; Port of Charleston, South Carolina; and Port of Savannah, Georgia), via an ocean freighter meeting required safety and design standards. Each shipping container would accommodate four Model 30B cylinders with overpacks, or about 9 tonnes of UF_6 . Assuming one container of four cylinders per ship hold or defined deck area and eight holds or defined deck areas per ship, 32 cylinders (approximately 72 tonnes) of UF_6 would be transported in each ocean shipment. The size of the shipments can vary somewhat, depending

on ship design and spacing requirements, but this is representative of typical shipments. Based on this shipment size, it is estimated that, during the first 5 years of shipment, seven shiploads per year, or approximately one shipload every 2 months, would be required to transport the LEU; and that for the last 15 years, 19 shiploads per year (about one shipload every 3 weeks) would be required to transport the LEU. However, it is possible that one MTU of the proposed 500 MTU of HEU converted to LEU would be separately shipped, as an initial demonstration project for this proposed action.

- Transport of LEU from the port of entry to Piketon, Ohio. The LEU would be transported via commercial truck from the port of entry to the Portsmouth GDP at Piketon, Ohio. The LEU may be placed in a secure staging area in the vicinity of the wharf for a short period of time while awaiting truck transportation to the Portsmouth GDP. Each truckload can accommodate four Model 30B cylinders with overpacks, or 9 tonnes of UF_6 . Thus, there would be approximately eight truckloads of LEU for each ocean-going shipment. During the first 5 years of shipping, 50 truckloads per year (roughly four per month) would be required. For the last 15 years, 149 truckloads per year would be required (roughly 12 per month).
- Receipt of LEU by Portsmouth GDP at Piketon, Ohio. Upon arrival at the Portsmouth GDP, LEU composition and specifications may be verified for purposes of U.S. accountability and material acceptability. The LEU would be placed in the GDP inventory and made available to the U.S. commercial nuclear fuel fabrication market. Normal GDP enrichment and private sector fuel fabrication activities at different sites would continue to take place irrespective of the purchase of LEU by the U.S. from Russia.

2.2 ALTERNATIVES

This section briefly describes alternatives to the proposed action including the no action alternative.

2.2.1 No Action

The no action alternative would result in the U.S. deciding not to sign the contract with the Russian Federation to purchase LEU resulting from the dismantlement of nuclear weapons. It would mean that the non-proliferation, economic, environmental cleanup, and weapons conversion objectives of the U.S.-Russian Federation Agreement would not be met. It is probable that the Russians would seek other opportunities to dispose of HEU, LEU, or both on the world market.

2.2.2 Receipt at the Paducah Gaseous Diffusion Plant

The USEC also operates the Paducah GDP at Paducah, Kentucky. The Paducah GDP is currently authorized to process enriched uranium up to an assay of two percent U-235. Modifications are nearly complete at the plant that will permit the processing of enriched uranium with an assay of up to five percent U-235; however, these modifications are not expected to be completed before the proposed action would begin.

When the cylinders containing the UF_6 would arrive from Russia, the cylinders would be sampled to assure that the material meets all specifications for the manufacture of commercial nuclear reactor fuel. If the assay of the U-235 required adjustment to meet customer's requirements, the UF_6 would have to be fed into a gaseous diffusion plant for product quality adjustment. Since the Paducah GDP is not currently authorized to sample the UF_6 in the cylinders or feed the UF_6 if the assay is greater than two percent U-235, the Russian LEU, which would have an assay of 4.4 percent U-235, would not be able to be processed at the Paducah GDP if the UF_6 shipments began before authorization was granted. However, since the proposed action spans the time period in which the Paducah GDP is expected to be able to process UF_6 up to assays of five percent, the transportation risks of this alternative are assessed in Section 6.6.2.

2.2.3 Receipt at Fuel Fabricators, Domestic or Abroad

There are five fuel fabricators in the United States, with additional fuel fabricators in Japan, South Korea, Germany, the United Kingdom, France, Spain, and Sweden. However, product quality considerations make direct shipment to fuel fabricators unlikely. For some time, the USEC would want to sample each product cylinder at the GDP site prior to shipping to a fuel fabricator due to the unique nature of the process of making the LEU from HEU. Also, the Russian LEU would be delivered at U-235 assays which must be agreed to by the Russians and the USEC before customers actually place orders with the USEC. If the U-235 assay of the UF_6 from the Russian Federation did not closely match a customer's requirements, the U-235 assay would have to be adjusted at the Portsmouth GDP prior to delivery to the fabricators. Furthermore, since the U-234 and U-236 limits allowed in ASTM specification C996-90 (the basis for acceptance of the Russian LEU) are higher than what the fuel fabricators are currently willing to receive on a routine basis, some adjustment of the LEU product at the GDP may be required before shipment to a fuel fabricator.

2.2.4 Optional Transport Mode to the United States

Air transport of radioactive materials is typically used for rapid delivery when the half-life of the material is short and/or timely use of the material is required. If the speed of delivery is not a consideration, then large, frequent shipments of radioactive materials by air are unwarranted. Historically, large cylinders, such as the Model 30B, containing UF_6 have not been shipped by air due to the costs, which would greatly exceed costs for transport by marine vessel. However, for purposes of this analysis, the air transport alternative will be qualitatively assessed.

2.2.5 Transportation of LEU from Several Alternative Ports of Entry to Piketon, Ohio

The proposed ports of entry are Port of Hampton Roads, Virginia; Port of Baltimore, Maryland; Port of Philadelphia and South New Jersey, Pennsylvania and New Jersey; Port of New York and New Jersey, New York and New Jersey; Port of Houston, Texas; Port of Charleston, South Carolina; and Port of Savannah, Georgia. Any of these ports could be used for a portion or all of the shipments from St. Petersburg, Russia. Nevertheless, in order to compare the risks of using alternative ports, several ports on the East Coast of the United States, other than those listed above, and one West Coast port are analyzed.

Ships transporting the LEU from St. Petersburg to the United States would use normal shipping lanes through the Gulf of Finland, the Baltic Sea, the North Sea, and the Atlantic Ocean. Since the shortest, most frequently scheduled voyages from St. Petersburg to the United States arrive at the East Coast, it is unlikely that a ship carrying cargo destined for the Portsmouth GDP would use a West Coast port. If a Gulf Coast or West Coast port of entry were used, the shipping routes through the Gulf of Mexico or the Pacific Ocean would be significantly longer than those for East Coast ports. For example, the ocean transport distance from St. Petersburg to Hampton Roads is approximately 8,900 kilometers (4,800 nautical miles), while the distance from St. Petersburg to Oakland, California is 17,300 kilometers (9,330 nautical miles) [DMAHTC, 1991]. In addition, the distance a truck or train would have to travel from a West Coast port to Piketon, Ohio, is much greater than the distances associated with East and most Gulf Coast ports of entry. As a result, transportation costs would be greater due to the greater distances the LEU would have to be shipped. Thus, West Coast ports of entry may not be desirable alternatives from a transportation cost perspective.

Military ports have not been considered as possible ports of entry because USEC would be contracting with commercial carriers to transport the LEU and those carriers would use commercial ports since commercial ports are available. In addition, OMB Circular A-76 prohibits the Federal Government from competing for services when such services can be procured from the private sector. Substantial commercial port experience with handling UF_6 exists and the import and/or export of LEU is a common commercial transaction [JoC, 1993]. Military vessels and ports or other measures for the physical protection of LEU shipments are neither required nor practical. Since LEU cannot be used directly to fabricate a nuclear explosive, military vessels and ports are not required for safeguarding nuclear material. Furthermore, the radioactivity of LEU is so low that dispersal by manual means or acts of sabotage would not produce a significant radiological hazard [NRC, 1977] (although it would produce a chemical hazard similar to the accident described in Section 6.2.3). In addition, military bases may not have the experience or equipment to handle commercial vessels and their cargo. For example, Kings Bay Naval Base in Kings Bay, Georgia, is a submarine base and is not equipped with gantry cranes for loading and unloading container ships. Military bases also are likely to have personnel access restrictions for entry into their facilities. For example, Kings Bay Naval Base regulations prohibit foreign nationals

from entering the Naval Base. As a result, any vessel not manned entirely by United States citizens may be prohibited from using this port.

The transportation risks associated with military ports would be similar to those of commercial ports, with differences mainly arising in the distance from the Portsmouth GDP. For example, if the port of entry were the naval base at Kings Bay, Georgia, the overland transportation risk would be slightly less than the commercial port at Fernandina Beach, Florida which is about 40 miles further away from the Portsmouth GDP, only because of the slightly higher population density along the initial leg of the Fernandina Beach-Piketon overland transportation route.

The alternative ports were selected on the basis of geographic, physical, historic, and economic criteria. As a result of the criteria used, many of the ports selected could be characterized as high population density ports. Ports have historically been established in areas with inviting geographic, physical, and population attributes. Likewise, population centers have been established and grown in areas with appealing geographic/physical features and excellent transportation access. Thus, the busiest, most experienced, and typically best equipped ports are surrounded by relatively large populations in areas with good transportation links. However, in order to include ports that do not have a high population density among the alternatives, Morehead City, North Carolina (population density is 37 persons/km²), and Fernandina Beach, Florida (population density is 25 persons/km²), were included for analysis as potential ports of entry. It should be noted, however, that a current resolution by the City of Fernandina Beach, Resolution Number 801, prohibits the port of Fernandina Beach from importing hazardous materials without submission of an amended application for development. It is unlikely that a small port like Morehead City or Fernandina Beach would be used since the likelihood of an ocean-going commercial vessel making a St. Petersburg-Morehead City or St. Petersburg-Fernandina Beach voyage is small. Specification of a small port, such as Morehead City or Fernandina Beach, as the port of entry would probably require either trans-shipment of the LEU or arrangement of a special port of call. Trans-shipment would increase the incident-free (or routine) dose to cargo handlers and inspectors, even during routine operations. Furthermore, either option may entail additional fees for transporting the LEU, making small ports less attractive.

2.2.6 Transport of LEU within the United States by Rail

The proposed action would involve transporting the LEU by commercial truck from a warehouse/terminal at the port of entry to the Portsmouth GDP at Piketon, Ohio. Each truckload would comprise 9 tonnes of UF₆ contained in four Model 30B cylinders in overpacks, inside SEAPAK shipping containers. There would be eight truckloads of LEU for each shipment by ocean freighter during the proposed action. For the entire 20 years of the proposed action, a total of 2485 truckloads would be required to transport the LEU.

With respect to the rail alternative, the activities leading up to transport from the port of entry would be the same as for the proposed action. The difference between the rail alternative and the proposed action would be that the LEU would be transported by rail from a warehouse/terminal in the port of entry to the Portsmouth GDP. Each rail car would hold four Model 30B cylinders of LEU in their SEAPAKs, the same as a commercial truck. However, a number of rail cars could be accommodated in any one train. For example, an entire shipload of 32 Model 30B cylinders would fill eight rail cars. For the entire 20 years of the proposed action, a total of 320 trainloads would be required to transport the LEU.

SECTION 3.0

DESCRIPTION OF URANIUM ENRICHMENT

3.0 DESCRIPTION OF URANIUM ENRICHMENT

The following sections describe the uranium enrichment process and the operation of the two U.S. uranium enrichment plants. The information is provided as background for understanding the environmental consequences discussed in Section 6.0

3.1 THE URANIUM ENRICHMENT PROCESS

Commercial technologies enrich uranium processed from mined material to the desired U-235 assay level by one of two processes: gaseous diffusion or gas centrifugation. In the U.S., gaseous diffusion is used at the Portsmouth GDP at Piketon, Ohio, and the Paducah GDP at Paducah, Kentucky. Both of these plants are now operated by the USEC. These plants operate on the principle that lighter weight gaseous isotopes have slightly higher average velocities and thus can be made to diffuse through a porous barrier (tubes filled with extremely small holes) more rapidly than heavier species. In the process, UF_6 is heated to at least 134°F and converted from a solid to a gas. The UF_6 flows through a series of compressors and converters. Each converter contains thousands of porous barrier tubes. Each compressor/converter arrangement is called a stage. The compressor increases the pressure of the gaseous UF_6 so that it is forced to diffuse through the barrier tubes. Because U-235 has a smaller isotopic mass than U-238, it passes through the porous barrier more quickly, increasing the U-235 content of the diffused uranium. For each porous barrier passed, two streams are created, one which is enriched and one which is depleted in the lighter U-235 isotope. The uranium in the latter stream is called depleted uranium or "tails." The fraction of the U-235 isotope remaining in the depleted uranium from an operating enrichment plant is called the "operating tails assay."

The commercial transaction for enrichment work takes place as follows: A GDP enrichment service customer, usually a utility, desires a certain quantity of LEU containing a particular assay or quantity of U-235. In order to obtain the desired quantity and assay of LEU, the utility customer delivers UF_6 feed material to the GDP (usually natural UF_6 containing 0.711 percent U-235) and purchases enrichment services from the GDP. The cost of the enrichment services to a customer is expressed in terms of dollars per separative work unit (SWU). A SWU is the conventional measure of the effort achieved in a uranium enrichment plant after separating uranium of a given U-235 content into the two streams. When customers buy services from the GDP, they are buying separative work units (SWUs).

The relative amounts of feed material delivered to, and the enrichment services purchased from, the GDP by a customer are determined by the transaction tails assay (i.e., the tails assay at which that customer transacts with the GDP, which is generally about 0.28 percent U-235). If the GDP had only one customer, and the GDP did not have its own stockpile of natural uranium feed, then the GDP would use the feed delivered by the customer to operate at the tails assay specified by the customer to produce the LEU required by the customer. The GDP would collect revenues from the customer based on the amount

of enrichment services required to produce the LEU and the price of the SWUs. When the customer takes the LEU, the customer may also take or leave at the GDP the depleted uranium that results from producing the desired LEU. Nearly all customers elect to leave their depleted uranium at the GDPs.

In operating the Portsmouth and Paducah GDPs, the USEC utilizes the feed material delivered by all of its customers to produce the LEU required by the customers. In doing so, the operating tails assay of the GDPs is the average of the transaction tails assay specified by the customers. However, because the GDPs have their own stockpile of natural UF_6 , the GDPs can supply additional uranium feed to the plants, which will cause the operating tails assay to increase and will reduce the enrichment required to produce the LEU product. This process is called "overfeeding."

One of USEC's primary corporate goals is cost reduction. The major GDP production cost is the purchase of electric power. This represents about 70 percent of enrichment costs, since very large quantities of electric power are required to produce enriched uranium using gaseous diffusion technology. The most effective way to reduce enrichment costs is to reduce the electric power consumption of the GDPs by overfeeding the plants with feed material owned by the USEC.

3.2 GASEOUS DIFFUSION PLANTS AT PIKETON, OHIO, AND PADUCAH, KENTUCKY

The two gaseous diffusion plants in the United States are federal government facilities leased to the USEC by the DOE and managed for the USEC by a government contractor, Martin Marietta Utility Services, Inc. The Paducah GDP was constructed between 1951 and 1954 on a 5,000-acre site 16 miles west of Paducah, Kentucky. The Portsmouth GDP was constructed between 1952 and 1956 on a 4,000-acre site 3 miles south of Piketon, Ohio, and 22 miles north of Portsmouth, Ohio. While shipments of the Russian LEU under the proposed contract would be expected to be sent to Piketon, a description of the operation of both GDPs is included here since the Paducah GDP enriches UF_6 for use at the Portsmouth GDP.

Currently, the Paducah GDP is used to enrich 0.711 percent assay UF_6 to 1.9 percent U-235. The 1.9 percent assay UF_6 produced at Paducah is then transported to the Portsmouth GDP where it is enriched to the desired final product assay. The final product is transported from the Portsmouth GDP to the fuel fabricators. In addition, 0.711 percent feed is also fed to the Portsmouth GDP for enrichment. The Russian LEU would be placed in inventory at the Portsmouth GDP where, depending on the quality of the LEU and customer enrichment requirements, it may be fed into the GDP for product enhancement.

SECTION 4.0

HEU TRANSPARENCY

4.0 HEU TRANSPARENCY

HEU transparency refers to the ability of the Government of the United States, through the DOE, to gain confidence that the Russian LEU delivered to the United States under the proposed contract is derived from HEU, and that the HEU is being derived from dismantled nuclear weapons. Additionally, transparency refers to the ability of the Government of the Russian Federation to gain confidence that LEU delivered to the United States under the contract is used for commercial nuclear fuel fabrication. The USEC is responsible for all elements of the proposed action except transparency, which is the responsibility of DOE.

"The Memorandum of Understanding Between the Government of the United States of America and the Government of the Russian Federation Relating to Transparency and Additional Arrangements Concerning the Agreement Between the Government of the United States of America and the Government of the Russian Federation Concerning the Disposition of Highly Enriched Uranium Extracted from the Nuclear Weapons," signed on September 1, 1993, defines the measures to be used by monitors for the United States to achieve the transparency objectives. Specific details of transparency measures remain to be negotiated. For example, as part of these transparency measures, samples may be obtained by the United States monitors from the Russian materials. Up to eight samples could be taken each month from the HEU metal, the HEU in the form of UF_6 , and the LEU blendstock, as shown in Table 4-1. Samples would be taken and packaged in U.S.-supplied containers by Russian personnel in the presence of United States observers. The Russians would monitor the sampling process according to their health and safety procedures. All HEU and LEU samples would be shipped via commercial airline to a DOE laboratory such as Lawrence Livermore National Laboratory (LLNL) in Livermore, California. Samples would be analyzed at LLNL and other analytical laboratories within the United States. Most of the sample would be consumed in the analysis process; any sample remaining after analysis may be archived at LLNL or at the Y-12 Plant in Oak Ridge Tennessee, or managed as radioactive or mixed waste. A total of 1,920 g of U-235 in 90 percent enriched uranium metal, 13,040 g of U-235 in 90 percent enriched uranium hexafluoride, and 288 grams of U-235 in 1.5 percent enriched uranium hexafluoride could be sampled, shipped, and analyzed as part of the transparency activities for the 20-year period of the proposed contract. Thus, although specific details of transparency remain to be negotiated, these amounts represent the largest estimate of materials that would be shipped to the United States for transparency purposes.

The environmental impacts associated with the transparency activities would be minimal. All sampling and measurements would be performed by Russian plant personnel using equipment provided by the U.S. observation teams. U.S. representatives would not physically handle any HEU or LEU, containers, equipment or instrumentation during the sampling process. However, all sampling and measurements would be observed by U.S. personnel. During shipment, the transportation regulations for commercial air transport would be followed. These regulations specify a limit of 0.02 curies of fissile material per

Type A packaging (see Sections 2.1 and 6.2.). All quantities of HEU and LEU that would be shipped at any one time under the proposed action are categorized as Category IV nuclear materials per DOE Order 5633.3A. In accordance with DOE Order 5632.2A, Category IV materials do not require special safeguard considerations. The transportation risks associated with samples taken for transparency for incident-free and accident conditions are analyzed in Sections 6.2.2 and 6.2.3.

Table 4-1. Samples Taken According to the Transparency Protocol

	HEU Metal	HEU in the form of UF ₆	LEU Blendstock
Sample Mass (g)	1	6.8	0.15
Shipment Mass (g)	8	54.4	1.2
Yearly Mass (g)	96	652.8	14.4
Total Mass (g)	1,920	13,056	288

SECTION 5.0

DESCRIPTION OF AFFECTED ENVIRONMENT

5.0 DESCRIPTION OF AFFECTED ENVIRONMENT

Six environments potentially could be affected by the proposed action: the marine environment (Section 5.1), the U.S. ports of entry (Section 5.2), the truck or rail transportation corridors (Section 5.3), the Portsmouth GDP and locale (Section 5.4), the electric power industry (Section 5.5), and nuclear fuel cycle market industries (Section 5.6).

5.1 MARINE ENVIRONMENT

Because the proposed action involves ocean transport, the USEC considered the environmental impacts of this proposed action on the global commons, taking into consideration Executive Order 12114 [FR, 1981].

Ships transporting the LEU from St. Petersburg, Russia, to the East Coast of the United States would use normal shipping lanes through the Gulf of Finland, the Baltic Sea, the North Sea, and the Atlantic Ocean. If a port on the Gulf of Mexico were used, the ships would also transit the Straits of Florida and the Gulf. Figure 5-1 shows the proposed shipping lanes through which shipments of UF_6 would pass for most East Coast ports of entry. As explained in Section 2.0 a series of efforts were carried out to determine the likely routes shipping companies would use to transport cargo from St. Petersburg, Russia to the United States. The resulting list of proposed ports did not include any ports on the West Coast. Moreover, the distance a ship would travel from St. Petersburg to the West Coast of the United States and the distance a truck would travel from the West Coast to Piketon, Ohio, and, therefore, the associated costs, are much greater than the distances and costs associated with East or Gulf Coast ports of entry. For these reasons, a West Coast port of entry was not selected as a proposed port of entry (see Section 2.0). Therefore, the marine environments associated with West Coast ports of entry are not described.

Sea water is a complex solution containing a majority of the known elements. The average salinity of ocean water is about 35 parts per thousand. A significant feature of sea water is that while the total concentration of dissolved salt varies from place to place, the ratios of the more abundant components remain almost constant. This may be taken as evidence that over geologic time the oceans have become well mixed [Pickard, 1979].

There are two major sources of deep water in the world's oceans: a northern component found in the Norwegian, Greenland, and Labrador Seas, and a southern component from the Weddell Sea. The water from the Greenland Sea flows through the Denmark Strait and flows south down the western Atlantic after being joined by deep water formed in the Labrador Sea [NEA, 1988].

Figure 5-1. Map of Proposed Shipping Lanes

Specific flow estimates for the North Atlantic are up to $5 \times 10^6 \text{ m}^3/\text{s}$ for the total water volume crossing the whole Iceland-Scotland ridge [Steele, et al., 1962]. From the Greenland Sea the flow through the Denmark Strait has been estimated to be $5 \times 10^6 \text{ m}^3/\text{s}$ [Swallow, 1960]. Water from the Arctic that enters the Atlantic leaves mainly to the south toward midlatitudes [NEA, 1988]. The continental shelf extends from the shore with an average gradient of 1 in 500. The shelf has an average width of 65 km. Most of the world's fisheries are located on the continental shelf. The continental slope averages about 4000 m vertically from the shelf to the deep-sea bottom [Pickard, 1979].

An analysis of oceanic environments prepared by the Construction Engineering Research Laboratory (CERL), U.S. Army Corps of Engineers, provides valuable data on biotic resources, including whales, plankton, marlin, and four species of tuna, found in the North Atlantic [CERL, 1990]. The Right Whale, *Eubalaena glacialis*, was not considered by CERL, but is known to frequent North Atlantic waters. The National Oceanic and Atmospheric Administration (NOAA) recently proposed designation of a critical habitat for the Right Whale [FR, 1993]. The regions considered by NOAA include portions of Cape Cod Bay, Stellwagen Bank, and waters adjacent to Georgia and Florida. The latter designations include waters out to about 15 nautical miles from shore from the Altamaha River, Georgia, to Jacksonville, Florida (approximately between 30 and 31 degrees north latitude), which includes waters off Fernandina Beach; and out to about 5 nautical miles offshore at Sebastian Inlet, Florida (approximately between 28 and 30 degrees north latitude).

The deep sea bottom-dwellers are highly diverse, with many taxonomic groups being represented by more species than in most shallow water communities [Hessler and Sanders, 1967]. However, the number of individual organisms in a given area does decrease in the deep sea and this, together with a general tendency for the average size of the organisms also to decrease, results in a dramatic reduction in standing stock or biomass on the deep ocean floor. In round figures, the total wet weight of bottom-living organisms in and on each square meter of seabed decreases from 10-100 grams on the continental shelf, to 1-10 grams on the continental slope, and to only 0.1-1.0 gram on the abyssal plain [Rice, 1978].

Uranium is one of the elements naturally present in sea water. The uranium normally found in nature consists of three isotopes having mass numbers 234, 235, and 238. The ocean water concentration of U-isotopes is as follows: U-234, 1.04-1.3 pCi/l; U-235, 0.04-0.07 pCi/l; and U-238, 0.9-1.13 pCi/l [Cherry and Shannon, 1974]. One picoCurie (pCi) = $1 \times 10^{-12} \text{ Ci}$ or 0.000000000001 Ci.

The relationship between environmental concentrations of radionuclides and the concentration found in organisms is important in the study of food web effects. Bioamplification, the increase in concentration in organisms progressively further up the food web (as occurs with organic pesticides in terrestrial environments) is observed in marine food webs. In the marine environment, uranium has not been found to bioamplify in fish and only slightly bioamplifies in crustaceans and mollusks [IAEA, 1985].

In the marine environment the greater portion of the background dose rate to phytoplankton, zooplankton, and pelagic fish arises from incorporated activity. Alpha-emitting isotopes, particularly polonium-210 (Po-210), a progeny of uranium, is the main source of background dose and potassium-40 contributes most of the remainder [IAEA, 1976]. Concentrations of the naturally occurring Po-210 have been measured in mid-water crustaceans and fish to depths of 1500 m. Unusually high levels were found in certain benthic organisms, indicating that these organisms were exposed to particularly high natural radiation doses. The doses received were very large by human standards—up to approximately 400 rem/yr [Cherry and Heyraud, 1982]. The exposure of these organisms (marine invertebrates and fish) appears to make the oceans the highest known natural radiation domain in our biosphere. However, in general, aquatic organisms tend to be more resistant to radiation than terrestrial mammals [NCRP, 1991].

Since 1944, man has been discharging radionuclides into the oceans where the inventory of natural radioactivity is approximately 500×10^9 Ci [NAS, 1971]. As of 1981, it was estimated that man's total input of radionuclides, about 3 billion curies, essentially from waste disposal and nuclear weapons testing, approached 0.7 percent of the natural radioactivity in the world's oceans [Needler and Templeton, 1981].

5.2 PROPOSED U.S. PORTS OF ENTRY

One or more U.S. ports of entry could be used for import of the LEU into the United States. The ports are: Port of Hampton Roads, Virginia; Port of Baltimore, Maryland; Port of Philadelphia and South New Jersey, Pennsylvania and New Jersey; Port of New York and New Jersey, New York and New Jersey; Port of Houston, Texas; Port of Charleston, South Carolina; and Port of Savannah, Georgia. Each of these ports is briefly described in the following sections.

5.2.1 Port of Hampton Roads, Virginia

The Hampton Roads port complex, also known as the Ports of Virginia, is located at the confluence of the James River and the Chesapeake Bay, 18 miles from the Atlantic Ocean. Approximately 66 million tonnes of foreign trade cargo were moved through Hampton Roads in 1991 [VPA, 1992]. Foreign imports accounted for 7.9 million tonnes of this cargo. Hampton Roads is one of the largest natural deep-water harbors in the world and is the leading port in the U.S. in terms of total foreign waterborne commerce. In 1991, Hampton Roads was the leading East Coast port in terms of total cargo. There were approximately 6,300 arrivals and sailings at the port that year [VPA, 1992]. The surrounding population density is 1,433 person/km².

The majority of nuclear material shipments to the United States by sea has been shipped through the Hampton Roads facilities. Hampton Roads has a full-time Risk Management staff and many years of experience in handling nuclear materials. Port activities include U.S. Coast Guard inspections of ships and their cargo [U.S. Coast Guard, 1985], organizing overland carriers to receive the shipping containers,

providing on-site escorts and security, clearing the port weigh station for weighing prior to leaving port, and other safety and security measures. In the period August 1992-July 1993, approximately 3,560 metric tons of uranium products and 40 metric tons of other radioactive material were imported and exported through the Hampton Roads port complex [JoC, 1993].

The port is operated by Virginia International Terminals, Inc., for the Virginia Port Authority, which is an agency of the State of Virginia. Three separate marine terminals make up this facility: the Norfolk International Terminal, the Portsmouth Marine Terminal, and the Newport News Marine Terminal. A ship is directed to one of these terminals as it approaches the port. The terminal used is primarily a function of the type of ship and cargo and the shipping company.

5.2.2 Port of Baltimore, Maryland

The Port of Baltimore has a large terminal for importing and exporting automobiles and is rapidly growing, especially in the handling of containerized cargo. Approximately 21.8 million metric tons of foreign trade cargo were moved through the Port of Baltimore in 1991 [MPA, 1992]. Foreign imports accounted for 8.5 million tons of this cargo. There were 2,229 ship calls at the port that year. The population density of the surrounding urban area is 3,633 persons/km². Approximately 110 metric tons of uranium products and 90 metric tons of other radioactive material passed through the Port of Baltimore between August 1992 and July 1993 [JoC, 1993].

5.2.3 Port of Philadelphia and South New Jersey

The Port of Philadelphia and South New Jersey handles a great deal of bulk cargo, especially coal, meat, and fruit. The port has been increasing its crane inventory and other container handling capacity to accommodate growing demand. The Philadelphia and South New Jersey marine terminals are not on the coastline, but are 100 miles (160 km) up the Delaware River from its outlet in the Atlantic Ocean and are near heavily populated areas (population density 4,664 persons/km²). During 1991 there were approximately 20.7 million metric tons of foreign cargo imports moved through the port [MPA, 1992]. During 1992, 2,581 ships called at the ports. Approximately 26 metric tons of uranium products and 17 metric tons of other radioactive material passed through the Port of Philadelphia and South New Jersey between August 1992 and July 1993 [JoC, 1993].

5.2.4 Port of New York and New Jersey

The Port of New York and New Jersey handles the world's greatest volume of intermodal traffic, much of it ship-to-truck containers. Approximately 41.9 million metric tons of foreign trade cargo moved through the Port of New York and New Jersey in 1991 [MPA, 1992]. Foreign imports accounted for 34.8 million tons of this cargo. There were approximately 4400 container ship calls at the port during

1992. Population densities of areas near various terminals of the port include Brooklyn, 12,564 persons/km², Manhattan, 25,703 persons/km², and Elizabeth, New Jersey, 3,516/km². Approximately 1,860 metric tons of uranium products and 220 metric tons of other radioactive material passed through the Port of New York and New Jersey between August 1992 and July 1993 [JoC, 1993].

5.2.5 Port of Houston, Texas

The Port of Houston is not actually located on the Gulf of Mexico. Rather, access is through Galveston Bay and then 47 miles up the Houston Ship Channel. The Port of Houston Authority owns 42 general cargo wharves and two liquid cargo wharves. The Port ranked first in foreign import tonnage in the United States in 1991 with 37.2 million metric tons [MPA, 1992]. In 1992, approximately 65.3 million tons of foreign trade moved through the port [PoH, 1993]. During 1992, 5279 ships called at the port. The population density of Houston is 1161 persons/km². Approximately 690 metric tons of uranium products and 22 metric tons of other radioactive material passed through the Port of Houston between August 1992 and July 1993 [JoC, 1993].

5.2.6 Port of Charleston, South Carolina

The population density of Charleston is 753 persons/km². Approximately 8 million metric tons of cargo passed through the port in 1991 [MPA, 1992]. Foreign imports accounted for 2.6 million tons of this amount. Approximately 30 metric tons of uranium products passed through the Port of Charleston between August 1992 and July 1993 [JoC, 1993].

5.2.7 Port of Savannah, Georgia

The population density of Savannah is 998 persons/km². Approximately 9.8 million metric tons of waterborne commerce passed through the port in 1991 [MPA, 1992]. Foreign imports accounted for 4.5 million tons of this amount. Approximately 98 metric tons of uranium products passed through the Port of Savannah between August 1992 and July 1993 [JoC, 1993].

5.3 TRUCK AND RAIL TRANSPORTATION ROUTES

Historically, most shipments of LEU in UF₆ form in the U.S. have been made by commercial truck, the planned mode of transportation for the proposed action. Tables 5-1 and 5-2 contain the number of shipments and quantities of low enriched and natural uranium shipped within the United States in the past 10 years. Once the LEU arrives at one of the proposed ports of entry, it would be transported via local transportation routes to the nearest interstate highway. DOT routing regulations require that interstate system highways be used to the maximum extent possible. The HIGHWAY code [ORNL, 1992]

described in Section 6.2.1 and Appendix A was used to determine the distance traveled in areas of urban, suburban, and rural population zones for these highway routes.

Distances that trucks loaded with UF_6 would have to travel from the different terminals in each port of entry to the highway or interstate were measured from local maps. These distances and the population densities around the terminals were not generated by the HIGHWAY program. Instead, they were taken from actual U.S. census data.

**Table 5-1. Low Enriched Uranium (UF_6) Shipments
in the United States, 10/1/83-9/2/93 [Staggs, 1993]**

Fiscal Year*	Metric Tons Uranium	Number of Shipments
1984	17920	1909
1985	11090	1965
1986	9520	1617
1987	7719	1466
1988	7585	1467
1989	7648	1354
1990	7632	1408
1991	8508	1446
1992	8151	1970
1993**	8587	1709
Total	94360	16311

* Fiscal Year starts on October 1 and ends September 30.

** October 1, 1992 through September 2, 1993.

Table 5-2. Natural Uranium (UF₆) Shipments in the United States, 10/1/83-9/2/93 [Staggs, 1993]

Fiscal Year*	Metric Tons Uranium	Number of Shipments
1984	48766	2757
1985	33966	3515
1986	32034	3373
1987	34202	3156
1988	33240	3855
1989	36659	3105
1990	32714	3650
1991	40645	2948
1992	35538	2517
1993**	52854	2711
Total	380618	31587

* Fiscal Year starts on October 1 and ends September 30.

**October 1, 1992 through September 2, 1993.

5.4 GASEOUS DIFFUSION PLANT AT PIKETON, OHIO

The Portsmouth GDP is located immediately east of the Scioto River and three miles south of Piketon, Ohio. The plant has been in operation as a uranium enrichment facility since 1955. The same activities which would be required to handle the Russian LEU, i.e., the opening of overpacks, removal of Model 30B cylinders, sampling and placement of LEU in inventory for availability to nuclear reactor fuel fabricators, have been conducted safely at the plant since the United States began to provide fuel to the nuclear power industry. No new processes or equipment would be required to accommodate the Russian LEU.

The plant site lies in Pike County, Ohio, where the winters are moderately cold and the summers are moderately warm and humid. The soils at the site are strongly acidic, and soil productivity varies from low on steep uplands to very high on terraces and flood plains; texturally, the soils are predominantly silt loams. The terrestrial community comprises gently rolling hills, many of which have dry ridge tops, dry to moist slopes, and low-lying bottom lands. The vegetational community is dominated by a tree

cover consisting of white oak, red oak, and hickory. The animal species, their abundance, and their relative distributions are typical of those found in southern Ohio. Drainage from the entire area flows into various tributaries of the Scioto River, which in turn flows into the Ohio River at Portsmouth, Ohio.

The area surrounding the site is generally sparsely populated, marginal farmland [ERDA, 1977]. The State of Ohio Department of Natural Resources identified two threatened mollusks that occur in the Scioto River, near Piketon, Ohio; neither occurs on property owned by the Portsmouth GDP.

5.5 ELECTRIC POWER INDUSTRY

Gaseous diffusion plants are extremely energy intensive; electricity accounts for about 70 percent of the cost of producing a SWU. The Portsmouth GDP currently averages approximately 1,650 MWe of electrical power annually for operations, and the Paducah GDP averages approximately 1,500 MWe annually. When the Atomic Energy Commission (AEC) constructed the gaseous diffusion plants in the 1950s, it was decided to obtain the tremendous amounts of power required by the plants from the commercial power industry rather than for the AEC to construct and operate its own generating plants. Since no single utility was able to supply the full requirements of the Portsmouth GDP when it was constructed, 15 operating utilities in the Ohio Valley area formed the Ohio Valley Electric Corporation (OVEC) and its wholly owned subsidiary, the Indiana-Kentucky Electric Corporation. Problems with coal supply and the desire to place its two plants in different coal markets led OVEC to split its generating facilities and construct them further from the GDP than was done at Paducah. OVEC constructed the two plants on the Ohio River and connected them with a 345 kV transmission network. The 1,303 MWe Clifty Creek Station was constructed near Madison, Indiana, and the 1,086 MWe Kyger Creek Station was constructed near Gallipolis, Ohio. The Portsmouth GDP is the sole customer of these two dedicated plants. The OVEC contract provides DOE with approximately 1,950 MWe of essentially firm power (power that a utility must stand ready to supply even when the maximum demand for power is made on the utility) on a cost-sharing basis, where the price of power is based upon the cost to generate power at the two plants.

The AEC elected to split the supply of power for the Paducah GDP between the Tennessee Valley Authority (TVA) and a group of private utilities. The private utilities formed Electric Energy Incorporated (EEI) to provide their portion of the Paducah GDP's power requirement. EEI constructed the 1,010 MWe capacity Joppa Steam Plant across the Ohio River from the Paducah GDP. The contract between AEC and EEI was a cost-sharing contract. To supply its share of the load, TVA constructed the 1,440 MWe Shawnee Steam Plant adjacent to the Paducah GDP. However, the TVA contract treated the power as system power priced at system rates.

As the cost of TVA's system power rose, DOE sought cheaper sources of electric power for the Paducah GDP and began purchasing nonfirm power. Nonfirm power refers to power that is expected to be

available either at night or on weekends, or for a few days and possibly up to several months or longer. The cost for nonfirm power is lower than that for firm power since the power is sold when available and is subject to rapid termination when system conditions indicate a need. Some of the nonfirm power used by the Paducah GDP comes from nuclear units. The use of nonfirm power also minimizes the amount of firm power under long-term contract, thus reducing the risk of paying unused demand charges in the future.

Under the terms of the present contract, DOE is entitled to 75 percent (approximately 650 MWe-yrs delivered) of the Joppa plant's annual generation through 1993, and 60 percent (approximately 510 MWe-yrs delivered) thereafter. The contract also provides a mechanism to purchase nonfirm power from EEI sponsoring companies and other interconnected utilities. Fifty-six percent of the SWUs produced at Paducah in 1992 were produced using nonfirm power.

Since all nonfirm power purchased at Paducah comes through EEI sponsors and EEI, it is not possible to establish the original generator or ultimate fuel supplier of all the nonfirm power. However, a partial list of original power suppliers has been developed as follows:

Alabama Power Co.	Kansas City Power and Light Co.
Arkansas Power and Light Co.	Kansas Power and Light Co.
Big Rivers Electric Corp.	Kentucky Utilities
Central Illinois Public Service	Northern States Power Co.
Commonwealth Edison	Northern Indiana Public Service Co.
East Kentucky Power Cooperative	Public Service of Indiana
Electric Energy Inc. - Joppa	Sho-me Corporation
Illinois Power	Southern Illinois Power Cooperative
Iowa Public Service Co.	Tennessee Valley Authority
Iowa Southern Utilities Co.	Union Electric
Iowa Power and Light Co.	Wisconsin Electric Power Co.
Kansas Gas and Electric	

5.6 NUCLEAR FUEL CYCLE MARKETS AND INDUSTRIES

The steps in the nuclear fuel cycle, depicted in Figure 5-2, consist of mining and milling, conversion, uranium enrichment, fuel fabrication, energy generation, reprocessing (in the closed fuel cycle), and storage of depleted uranium (tails). Since the late 1970s, the United States has abandoned reprocessing as part of the domestic nuclear fuel cycle. The front end of the nuclear fuel cycle consists of uranium

Figure 5-2. The Nuclear Fuel Cycle

mining and milling, conversion, enrichment, and fuel fabrication. Once fabricated into the form required for use as reactor fuel, the uranium is used to produce electric power. The status of the front end of the nuclear fuel cycle and nuclear power production is provided in this section, followed by a description of the market for these products and/or services.

5.6.1 Uranium Mining and Milling

Mining and milling produces the uranium (known as uranium oxide (U_3O_8) or "yellowcake"). The major uranium mining and milling producing companies, and their countries of origin, are:

- Kazakhstan State Atomic Energy & Industrial Corporation (Kazakhstan)
- Cameco (Canada)
- Cogema (France)
- Rio Tinto Zinc (United Kingdom)
- Minatom (Russia)
- Navoi Uranium Combine (Uzbekistan)
- ERA (Australia)
- Uranerz (Germany)

In 1991, the largest U.S. uranium mines were located in Texas and Wyoming and were operated by Rio Grande Resources and Pathfinder Mines, respectively. Mining accounts for about 33 percent of U.S. uranium production [DOE/EIA, 1992]. All other U.S. uranium production in 1991 (67 percent) was produced by *in situ* leaching (in Texas, Wyoming, and Nebraska) or as a byproduct of phosphate production (in Florida and Louisiana). The major uranium mining and milling locations in the world are:

- Key Lake and Rabbit Lake (Saskatchewan, Canada)
- Rossing (Namibia)
- Akouta and Arlit (Niger)
- Ranger and Olympic Dam (Australia)

In 1991, the U.S. was the fourth largest uranium producing country in the world, behind Canada, Kazakhstan and Australia, but with only marginally greater production than that of Russia and Uzbekistan. U.S. uranium production in 1992 was approximately six million pounds, less than seven percent of the Western world's uranium requirements of 90 million pounds. Much of the U.S. uranium production is owned or controlled by foreign countries. Cogema, Total, EdF (France), Uranerz (Germany), and Nuclear Electric (UK) own subsidiaries that produced uranium in the United States during 1991. Utilities from Taiwan, Korea, and Switzerland also have (or once had) interests in U.S. uranium properties, mines, or mills.

U.S. uranium oxide production historically has been quite sensitive to developments in the current market (or spot) price. Not surprisingly, employment in the U.S. uranium mining and milling industry has been quite sensitive to the level of production. These relationships are shown in Figures 5-3 and 5-4, which examine not only the historical relationships, but the future relationships based on recent projections by the U.S. Energy Information Administration (EIA).

Figure 5-3. Comparison of Spot Price (1991\$) with U.S. Uranium Production, 1979-2005
[DOE/EIA, 1992]

Figure 5-4. Comparison of U.S. Uranium Production with Employment, 1975-2005
[DOE/EIA, 1992]

Figure 5-3 compares historical and projected spot prices (expressed in constant 1991 dollars) with historical and projected U.S. uranium oxide production. As is evident, a close relationship has existed historically, and the Energy Information Administration (EIA) forecasts that this correspondence will persist into the future. Figure 5-4 shows a similarly close correspondence between changes in U.S. production and employment. As shown, immense reductions in uranium oxide production and employment have already taken place due to lower prices. Increases in uranium industry employment in the future are only possible if production increases above the levels shown.

Over the 1992-2005 period, EIA forecasts that the uranium oxide spot price, U.S. uranium oxide production, and employment in the uranium oxide production industry will all more or less double. The forecast shown in Figure 5-3 predicts spot price increases from \$9.20 per pound in 1992 to \$18.10 per pound in 2005, and production increases from 5.7 million pounds to 11.4 million pounds U₃O₈ during the same time period. Employment increases are predicted from 800 person-years in 1992 to 1800 person-years in 2005 as shown in Figure 5-4. Using this as a basis, each \$1 change in price would result

in approximately a 650,000 pound change in production, and each 650,000 pound change in production would result in approximately a 110 person-year change in employment.

Employees in the uranium production industry are moderately to highly skilled. Uranium exploration, mining, and milling require personnel with varied backgrounds, including geologists, mining engineers, chemical engineers, equipment operators, maintenance workers, and administrative personnel to run these operations and market uranium. This employment is somewhat geographically concentrated, as uranium mines and processing facilities are for the most part located at uranium deposits in the western United States.

5.6.2 Uranium Conversion

Uranium conversion in the nuclear fuel cycle refers to the conversion of uranium oxide to uranium hexafluoride (UF_6) gas. There are five large-scale commercial convertors in the world:

- Comhurex (France)
- British Nuclear Fuels Limited (UK)
- Cameco (Canada)
- ConverDyn (US)
- Minatom (Russia)

ConverDyn is a new company formed by the merger of segments of the Allied Signal and General Atomics UF_6 marketing functions, and is the exclusive marketing agent for the UF_6 produced by Allied Signal. Allied Signal operates the only uranium conversion plant in the United States. This plant, located in Metropolis, Illinois, has a nameplate capacity of 12,600 MTU per year. General Atomics' Sequoyah Fuels plant, in operation until 1992, has been placed on indefinite standby status, and the existing General Atomics contracts have been taken over by ConverDyn. Other countries with uranium conversion capacity include Canada, France, South Africa, the United Kingdom, and Russia.

The current price (in constant dollars) of the uranium conversion process is less than it was ten years ago and competition is strong. Prices are apt to remain depressed until the production capacity is reduced. Presently, there is an oversupply of conversion capacity and little growth in demand.

5.6.3 Enrichment

The assay level of the UF_6 from the conversion plant is increased (enriched) at an enrichment plant to meet a utility's specified assay level of 3-5 percent U-235. There are four major enrichers in the world uranium market:

- USEC
- Eurodif
- Urenco
- Minatom

The USEC leases and operates two enrichment plants—one at Paducah, Kentucky, and the other at Piketon, Ohio—from the DOE. Eurodif operates one enrichment plant in France. Urenco, a consortium of British, Dutch and German interests, operates three plants: one in Capenhurst, United Kingdom; the second in Almelo, the Netherlands; and the third in Gronau, Germany. Minatom operates four plants in Russia: Yekaterinburg, Tomsk, Krasnoyarsk, and Angarsk. There is also a small amount of enrichment capacity in Japan and South Africa. Prior to July, 1993, when the USEC assumed responsibility for the enrichment operation, the DOE was the largest supplier of enrichment services in the world, although its position had steadily eroded since the mid-1970s. DOE's share of the world enrichment market has declined from 100 percent to about half of its previous market share. In 1991, the U.S. filled slightly under half of the Western world's enrichment requirements. At 19.2 million separative work units (SWU) per year, USEC's capacity is almost double the 10.8 million SWU/year produced by Eurodif, and the 10 million SWU/year the Russians state they are prepared to export to the West [Longenecker, 1991].

A private enrichment facility has been proposed in Louisiana, but the facility is presently only in the early stages of the NRC licensing process.

5.6.4 Fuel Fabrication

Fuel fabricators convert the enriched UF_6 to uranium oxide pellets. These pellets are placed in fuel rods and bundled according to a utility's specification. The fuel rod bundles are shipped to a utility to be placed in a reactor core.

Most countries with large civil nuclear power programs have their own fuel fabrication facilities; some with smaller programs do as well. Belgium, Brazil, France, Germany, India, Japan, South Korea, Russia, Spain, Sweden, United Kingdom, and the United States have fuel fabrication facilities for light water reactors (LWRs). The major fabricators and countries of origin are:

- Westinghouse (U.S.)
- Babcock & Wilcox Fuel Co. (U.S.)
- General Electric (U.S.)
- ABB-Combustion Engineering (U.S.)
- Siemens Nuclear Power Corporation (U.S.)

- ABB Atom (Sweden)
- Advanced Nuclear Fuels GmbH (Germany)
- British Nuclear Fuels (U.K.)
- France-Belge de Fabrication de Combustibles (France/Belgium)
- Japan Nuclear Fuel (Japan)
- Mitsubishi Nuclear Fuel (Japan)

The five U.S. companies together represent 45 percent of the Western world's fabrication capacity.

5.6.5 Nuclear Power Generating Capacity

The U.S. is the largest market for the products and services of the nuclear fuel cycle. It has the largest nuclear power generating capacity in the world with 111 plants producing about 100,000 megawatts of electric power (MWe) [DOE/EIA, 1992]. However, only a few plants are actively under construction. No new plants have been ordered in more than a decade and no new orders are contemplated before the mid-1990s. It is expected that no significant additional nuclear capacity will be operating in the U.S. before the year 2010 due to the time required to license, construct, and gain confidence in the new designs being developed.

The nuclear capacity in the U.S. may diminish if less cost-efficient plants are shut down prior to the end of their 40-year licensing period and/or their licenses are not renewed. Two such shutdowns have recently been announced. Thus, there are indications that the demand for nuclear fuel cycle goods and services in the U.S. will, at best, remain constant for the next twenty years and may even decrease during that period. While the growth in nuclear power programs in the rest of the world has generally slowed, it is still projected that modest growth of about 10 percent will occur [DOE/EIA, 1992].

5.6.6 The Uranium Service Market

The commercial nuclear fuel cycle market evolved out of the U.S. government's uranium procurement program for nuclear weapons production. The AEC initiated a procurement program which provided incentives for uranium ore exploration and agreed to buy all the uranium ore delivered at a set price. The incentives were such that, by the 1960s, the AEC had largely satisfied its needs, and the procurement program was phased out. The uranium oxide requirements for the infant nuclear energy industry at that time were much smaller than the available production capability. This led to low prices and a substantial contraction in the industry.

After the rapid increase in oil prices in 1973-1974, the pace of new orders for nuclear power plants throughout the world accelerated. Consequently, there was a perception of future shortages of uranium oxide. Uranium oxide prices quadrupled over a three-year period (1975-1978) as a result. This

prompted exploration for new supplies. Discovery of new low-cost ores and reductions in demand due to the economic impact of the second oil price shock and reactions to the accident at Three Mile Island resulted in an oversupply of uranium oxide in the late 1970s. As a result, the price of uranium oxide fell. By the early 1980s, the price of uranium oxide had declined to about the price level of the 1960s.

The price of uranium oxide has continued to decline through the 1980s and early 1990s due to the entry of the former Soviet Union into the market with its low-cost uranium oxide, and the further discovery of large, low-cost uranium ore deposits in Canada, Australia, and Africa. Currently, the price of uranium oxide in constant 1991 dollars (approximately \$10 per pound) is at its lowest level since the inception of the commercial market. The current low spot market price of uranium oxide is projected to persist through 1996 and then to increase at about 6 percent annually through 2005 [DOE/EIA, 1991b].

The low price of uranium oxide has caused many of the mining and milling production facilities in the U.S. to shut down. Total U.S. production of uranium oxide has fallen from a high of 44 million pounds in 1980 to a low of eight million pounds in 1991 [DOE/EIA, 1992]. Most (67 percent) of the 1991 uranium production did not come from mining activities, but was produced either as a by-product of phosphoric acid production or by *in situ* leaching. Worldwide production outside of the historical Soviet block countries has fallen as well (from 130 million pounds in 1980 to 81 million pounds in 1990), but not nearly as precipitously as in the U.S. The large decrease in U.S. production has been partially compensated for by increases in production in Canada and Australia.

Major uranium oxide inventories are held by utilities, uranium producers, brokers and governments. The content of government stockpiles is not generally known; however, the commercially-owned inventory in the U.S. is equivalent to 120 million pounds of uranium oxide [DOE/EIA, 1992]. Of this inventory, about 40 million pounds are required for the fuel pipeline, leaving about 80 million pounds available to cover U.S. production shortfalls. The rate of inventory drawdown is projected to decrease over time with the inventory eliminated by 1998 or 1999 [DOE/EIA, 1991b].

The 1991 uranium oxide requirement of U.S. nuclear power plants was about 42 million pounds, while domestic production was only eight million pounds [DOE/EIA, 1991a]. The balance of 34 million pounds was made up from imports and inventory drawdowns of both uranium oxide and LEU. The annual domestic supply of uranium for the years 1993 - 2005 is expected to be as follows:

- domestic production 15-20 percent
- importation 75-80 percent
- inventory drawdown 5-10 percent

The U.S. went from being a net exporter of uranium in 1980 to importing some 50 percent of requirements in 1991, and will import more than 80 percent of requirements early in the next century.

The Secretary of Energy has made the determination that the U.S. uranium mining and milling industry has not been viable in terms of production since 1984 [DOE/EIA, 1991b].

The U.S. market for nuclear fuel is different from other geographic markets in several ways. The U.S. currently has a restriction on the importation of uranium oxide and enriched uranium from the Commonwealth of Independent States (CIS). This restriction is in the form of two different types of quotas. The first allows a certain amount of CIS uranium oxide to be delivered under existing long-term contracts, while the second permits new sales of CIS uranium oxide to the U.S. based on a published price/quantity schedule.

Other countries in the world market do not have this type of quota on CIS uranium oxide. However, countries in the European Community (EC) have what may be considered an informal quota on CIS uranium oxide and enrichment services, administered by the Euratom Supply Agency which oversees nuclear fuel contracting in the EC. Euratom has pursued a policy to limit the reliance of the EC on nuclear fuel imports from any one particular country or region. To this end, and to protect nuclear fuel suppliers in the EC, Euratom has refused to approve CIS contracts if they would result in too great a reliance on CIS supplies or call for a price less than the prevailing market price.

The actions of the U.S. government and Euratom have led to creation of a two-tier price for uranium oxide, uranium conversion, and enrichment. The broker/trader Nuexco has begun publishing a Restricted American Market penalty to reflect the higher prices that U.S. consumers must pay for uranium due to the U.S. quota on CIS supplies. Effectively, this higher price also must be paid by EC utilities and other utilities which will not or cannot buy CIS supplies.

The persistence of this two-tier price depends in large part on the strength of the Euratom resolution to maintain its restriction on CIS supplies. Recently, Euratom has been under some pressure to relax its limitation on CIS supplies, but so far has not amended its policy. A two-tier price has existed before in the uranium oxide market, when it appeared that DOE might restrict the enrichment of non-U.S. uranium oxide which would be used in U.S. reactors. That two-tier price persisted for 19 months, and ended when it became evident that the U.S. would not restrict the enrichment of non-U.S. uranium oxide.

The U.S. market is also different from other geographic markets because of the greater focus of U.S. utilities on spot versus term contracting, particularly in uranium oxide. The U.S. represents a disproportionately high percentage of the world's currently unfilled nuclear fuel needs because of U.S. utilities' preference for purchasing material under spot and short-term contracts. With some exceptions, U.S. utilities are also smaller in size, both absolute and relative to the national electricity supply as a whole. In comparison, the utilities Electricite de France (France), Ontario Hydro (Canada), Nuclear Electric (UK), Synatom (Belgium), Taipower (Taiwan), and Korea Electric Power (Korea), represent the vast share of their countries' nuclear electricity generation.

The U.S. market is also different from other geographic markets due to nonproliferation considerations. U.S. utilities can accept virtually all origins of uranium oxide for consumption, subject to the quota on CIS material discussed earlier. Because the U.S. places fairly stringent restrictions on the end-use of its nuclear fuel exports, including requiring prior consent for subsequent reprocessing, some countries prefer to receive uranium oxide from origins other than the U.S. Also, the U.S. cannot export nuclear material to those countries where it has not negotiated an Agreement of Cooperation. For instance, U.S. companies cannot currently send uranium to Russia for enrichment.

There is no direct U.S. government management of the uranium mining, uranium conversion, and fabrication industries, and little direct involvement in the utility industry. The U.S. utility industry is highly regulated, although mostly by individual states. The nuclear power industry is highly regulated by the U.S. Nuclear Regulatory Commission (NRC). This is in contrast to most other countries. There is some sort of government ownership of the uranium industries in Australia, Canada, France, Gabon, Namibia, Niger, and South Africa, as well as all of the CIS republics, Czechoslovakia, Bulgaria, Germany, and Hungary. There is government ownership or participation in the uranium conversion industries in Canada, France, UK, and Russia.

SECTION 6.0

ENVIRONMENTAL CONSEQUENCES

6.0 ENVIRONMENTAL CONSEQUENCES

In order to understand the potential for environmental effects related to the proposed action and the reasonable alternatives, it is important to understand some of the chemical and physical properties of the material being transported. Under the proposed action, the low enriched uranium would be transported as uranium hexafluoride in its solid form. In this form and under normal conditions, uranium hexafluoride (UF_6) is relatively stable. The compound tends to remain in a solid form because of its low vapor pressure at normal atmospheric temperatures and pressures. Unless the UF_6 is subjected to temperatures over about 130°F and less than atmospheric pressures, it is not readily susceptible to airborne transport and, as a consequence, presents a minimal toxicological health risk. This risk is further reduced by the packaging surrounding the material which prevents the UF_6 from coming into contact with outside air and moisture. When uranium and its progeny undergo radioactive decay, some gamma and x-rays will be emitted, but as a result of self-shielding¹, the shielding provided by the cylinder, and the relatively low energy of the gamma and x-rays, UF_6 presents a minimal external radiation health risk.

6.1 CHEMICAL FORMS AND PATHWAYS

If the physical form of UF_6 changes to either a gas or a liquid, its potential for toxicological and radiological risk from both internal and external exposures increases. To change the physical form of UF_6 from a solid, heat and pressure must be supplied. As noted in Section 3.1, the cylinders containing the UF_6 are heated to at least 134°F to convert the solid UF_6 into a liquid and then a gaseous form for injection into the gaseous diffusion process. If released as a liquid as a result of a cylinder rupture during this heating process, UF_6 vaporizes instantly to particulates and gas. As a gas, UF_6 reacts with water vapor in the air to produce uranyl fluoride (UO_2F_2) and hydrogen fluoride (HF) which is seen as a white cloud. This cloud would be transported by air and is respirable.

Nationally accepted standards for occupational exposure to chemicals are stated in terms of threshold limit values (TLVs), which are established by the American Conference of Governmental Industrial Hygienists (ACGIH). The TLV represents a time-weighted average air concentration to which nearly all workers

¹ "Self-shielding" refers to the shielding which would be provided by the material itself between radiation resulting from radioactive decay and a receptor.

can be exposed for a normal 8-hour day, 40-hour work week over a working lifetime without adverse health effects (Sax and Lewis, 1987). An air concentration of a contaminant can be compared to the TLV to determine the relative impacts to humans from an exposure. TLVs are based on the dose-response relation between the agent and its health effects on the worker. This relationship is of a graded nature; consequently, there is a lower level of exposure at which the worker will experience no deleterious effect from the substance. Due to individual variations in susceptibility and many unknown factors in the working environment and their effects on a given toxic material, the TLV of a material is not a fine distinction between a safe and dangerous condition. However, TLVs are a useful tool in evaluating the hazardous nature of a substance, and in providing personnel protection against exposures.

In addition to the TLV, there is an Immediately Dangerous to Life or Health (IDLH) level that represents the maximum concentration from which individuals could escape within 30 minutes without experiencing any escape-impairing or irreversible health effects [NIOSH, 1990]. TLVs and IDLH levels have been established for HF and for uranium, as shown in Table 6-1.

Table 6-1. TLVs and IDLH Levels for Airborne Concentrations of Hydrogen Fluoride and Uranium (expressed as milligrams [mg] of substance per cubic meter of air [m³])

Material	TLV (mg/m ³)	IDLH (mg/m ³)
HF	2.5	25
Uranium	0.2	30

Fluoride component

Hydrogen fluoride is a gas at room temperature and pressure, is corrosive and has a strong, irritating odor. It exhibits chemical toxicity when ingested or when inhaled for more than a few minutes at levels of 13.3 mg/m³ or greater. In the presence of water, gaseous HF reacts to form hydrofluoric acid. External contact with hydrogen fluoride at levels above 0.26 mg/m³ causes severe irritation of eyes and eyelids and may result in prolonged or permanent visual defects or total destruction of the eyes. Skin contact with hydrogen fluoride may result in severe burns [Merck Index, 1983].

The health effects of internal contact (inhalation) of hydrogen fluoride depend on the concentration and duration of the exposure. Figure 6-1 shows health effects that result from inhalation of HF based on the concentration and the time of exposure. The toxicity of acute exposures to HF can be characterized into five general levels which are associated with odor or irritation: (1) below level of odor detection, (2)

smell/no health effects, (3) smell/possible irritation, (4) irritation/possible health effects, and (5) lethal [IAEA, 1991].

Uranium component

Uranium compounds UO_2F_2 and UF_6 exhibit both chemical and radiological effects when inhaled or ingested by humans. However, UF_6 and UO_2F_2 are soluble and tend to be eliminated relatively rapidly from the body. As a result, they present minimum radiological hazards. The relatively rapid elimination of highly soluble UF_6 and UO_2F_2 means that it is the chemical toxicity, rather than radiological impact, that presents the chief potential adverse health effect from an absorbed dose of soluble uranium. An absorbed dose of 0.03 milligrams (equivalent radioactivity 0.16 microcuries) of soluble uranium per kilogram of body weight normally would result in no acute health effects (see Table 6-2). However, as the absorbed dose increases, the potential for acute health effects increases.

Table 6-2. Comparison of Chemical Toxicity and Radiotoxicity of Soluble Uranium at 97.5 Weight Percent U-235 and 1.14 Weight Percent U-234 Enrichment [Martin Marietta, 1985]^a

Absorbed Dose of Soluble Uranium (mg-U/kg body weight)	Equivalent Radioactivity (μCi)	Acute Health Effects	
		Chemical Toxicity	Radiotoxicity
0.03	0.16	No effect	No effect
0.058	0.30	Renal injury	No effect
1.63	8.45	50% lethality	No effect
19.29	100	Lethal	Onset of radiological effects
^a Although enrichments less than 5 percent U-235 will be purchased under the proposed action, 97.5 percent U-235 is used for conservative dose calculations.			

As shown in Figure 6-2, four acute health effects levels have been associated with inhalation of soluble uranium compounds: (1) no effect, (2) renal injury, (3) lethality in 50% of the exposed population (LD_{50}), and (4) lethal to all exposed. Estimates of uranium toxicity for exposure times greater than 60 minutes should be based on extrapolation of the 60-minute toxicity estimates shown in Figure 6-2.

Figure 6-1. Toxicity of Acute Exposures to Hydrogen Fluoride [IAEA, 1991]

Figure 6-2. Toxicity of Acute Exposures to Soluble Uranium [IAEA, 1991]

6.1.1 External Radiation Exposure

Natural uranium is composed of the radioactive isotopes U-234, U-235, and U-238 which, upon decay, emit various forms of ionizing radiation. The health effects that an individual may suffer as a result of exposure to ionizing radiation depends on the type of radiation, the dose, and the rate at which it is received. Dose to an individual is expressed in rem, a unit of dose equivalent. The dose equivalent in rem is numerically equal to the absorbed dose in rad multiplied by the quality factor, the distribution factor, and any other necessary modifying factors. An acute (short-term) external exposure to large doses of radiation greater than 10 rem can result in the immediate onset of health effects. All of the incident-free doses that could result from the proposed action are much lower than 10 rem and would be received over several months (the maximum annual dose to the maximally exposed worker associated with the proposed action would be 0.0041 rem; see Section 6.2.2). A low dose delivered over a long period of time is known as a chronic exposure. Such a dose would not result in the onset of immediate health effects, but long-term exposure could contribute to an increased likelihood of cancer. During incident-free transportation, individuals near the cylinders containing the LEU would be exposed to low-levels of external radiation (gamma and x-rays) emitted by the LEU. This exposure is possible since some of the electromagnetic waves of radiation (gamma and x-rays) generated during the radioactive decay of the uranium and its daughter products in the cylinder would be able to penetrate and escape the cylinder walls. No internal exposures would be received since the UF_6 and any alpha and beta particles emitted during the decay of uranium would be contained within the cylinder, and therefore would not be available for inhalation or ingestion.

The National Academy of Sciences gives a lifetime risk of a radiation-induced cancer fatality of about 4 in 10,000 (0.0004 or 4×10^{-4}) fatal cancers per rem of exposure for workers (i.e., persons between 18 and 65 years old) and 5 in 10,000 (0.0005 or 5×10^{-4}) fatal cancers per rem for the general population [NAS/NRC, 1990]. For example, if a worker is exposed to one rem, that person is estimated to have a four-hundredths of a percent (0.04 percent) chance of dying from a cancer resulting from the one rem exposure. In comparison, the worker has a 20 percent chance of dying from cancer resulting from causes other than radiation [NAS/NRC, 1990]. The higher risk value given for the general population reflects the younger ages present in the general population when compared to the worker population. Children appear to be at greater risk of dying from cancer as a result of exposure to radiation than adults. The higher risk estimate for the general public (0.0005 fatal cancers per rem) has been adopted by the NRC in its regulations setting maximum radiation dose limits for protection of individual members of the public [FR, 1991]. These risk estimate values are also used in the risk analysis in this EA.

The impact of external radiation exposure to a large population (not an individual) is expressed in terms of person-rem. A person-rem is the unit used to express the sum of all doses received by individuals in a population. The same cancer risk value used to assess health effects to a large population (0.0005 or 5×10^{-4}) is used to assess the risk to an individual. The cancer risk value is based on a population of

100,000 people exposed to an acute dose of 10 rem. Thus, the application of the cancer risk value is more appropriate when used to assess the health effects for a large population exposed to high doses versus a specific individual exposed to low doses. Using the cancer risk value to assess health effects for a specific individual exposed to doses much lower than 10 rem tends to overestimate the actual cancer risk.

6.2 POTENTIAL TRANSPORTATION IMPACTS

The methods of analysis and the results of the analysis of risks associated with the transportation of LEU from St. Petersburg, Russia, to the Portsmouth GDP at Piketon, Ohio, are summarized in this section. The transportation risks for the alternative ports of entry are compared to those for the proposed action in Section 6.6.

It is important to recognize that low enriched UF_6 is a relatively stable compound that has a very low specific activity. Each Model 30B cylinder containing 2250 kilograms of UF_6 would have an activity of about 5 curies. UF_6 contains only uranium and its daughter products. The low-energy gamma and x-rays resulting from the decay of uranium and its daughter products present a minimal external radiation hazard. While the range of forces potentially brought to bear on a package during an accident is the same for any given mode of transportation or handling, regardless of the package (assuming no extraordinary measures such as convoys, escorts, etc.), the response of the package, however, differs according to the characteristics of the package and its contents. It is the package and content response that determines the consequences of an accident. The transportation analysis for the proposed action considers a range of possible accident scenarios that are the same as those applicable to shipments of spent nuclear fuel (see Section 6.2.3 "Overland"). However, adjustments were made to the calculation of accident risk to account for the difference in packaging, including number of packagings, and content response of various accidents involving breach of package between potential accidents associated with low enriched UF_6 and those associated with spent fuel.

Shipments of UF_6 in a solid state would be made in Model 30B cylinders that meet all U.S. and international radioactive material packaging requirements. A Model 30B cylinder meets DOT requirements for Type A packaging. Type A packaging is sometimes called strong, tight packaging. The DOT's regulations treat UF_6 , when enriched to less than 20 percent U-235, as presenting a sufficiently minimal radiation hazard that an "unlimited" quantity of uranium can be shipped in Type A packaging [DOT, 1990]. All cylinders, including those fabricated outside of the U.S., must comply with the American National Standards Institute (ANSI) standard: ANSI N14.1-1990 Packaging for Transport. ANSI develops packaging standards in cooperation with the International Standards Organization. The standards provide specifications for package design, fabrication, loading, shipping, and requirements for valves, valve protectors, inspection, cleaning, and maintenance. DOT regulations on authorized packaging of fissile materials in 49 CFR §173.417 require that handling procedures and packaging criteria

be in accordance with the DOE report, "Uranium Hexafluoride: A Manual of Good Handling Practices" [ORO, 1991].

For purposes of safety, cylinders used to transport UF_6 are overpacked to provide resistance to impact and fire damage and to maintain the temperatures needed to ensure that the UF_6 remains at a safe temperature and pressure. A number of protective overpacks have been designed and tested in accordance with DOT and NRC regulations for the Model 30B cylinder. The DOT specification horizontally loaded overpack for the Model 30B cylinder is the 21PF-1B. The 21PF-1B overpack is a fire- and shock-resistant phenolic-foam insulated metal overpack that weighs 800 kilograms (1,750 pounds). Detailed specifications are found in 49 CFR §178.358 [DOT, 1990].

Type 30B cylinders in their overpacks are also certifiable as Type B packages. Type B packages are required to pass two series of rigorous tests: those associated with normal or routine transport and those associated with hypothetical accident conditions that might be encountered. The accident conditions are listed in Table 6-3. The result is that UF_6 transport packages can withstand all reasonably foreseeable accidents, including very severe accidents, involving handling and transporting the packages by ship or truck. However, to estimate the risk of an accident the probability that an accident would occur has to be estimated. Given that no accident involving the loss of radioactive material from a Type B packaging has ever occurred, the probability of an accident occurring was nevertheless estimated by conservatively extrapolating from historical data involving less secure packagings. The extrapolation provides a method to estimate the probability of a container breach during an accident even though such an accident has never occurred and is not expected to occur.

Table 6-3. Hypothetical Accident Conditions for Type B Packages

ACCIDENT	CONDITIONS
Free Drop	Free drop through a distance of 30 feet (9m) onto a flat unyielding surface, striking the surface in a position for which maximum damage is expected.
Puncture	Followed by, free drop through a distance of 40 inches (1m) in a position in which maximum damage is expected onto upper end of solid steel bar.
Thermal	Followed by, exposure for not less than 30 minutes to thermal environment of 1475°F (800°C)
Immersion	Subjected to water pressure equivalent to immersion under a head of water of at least 50 feet (15m) for at least eight hours.

Source: Title 10, Code of Federal Regulations, Part 71, Subpart F.

6.2.1 Methodology

Transportation risk analysis of marine and overland transportation segments, as well as port operations, was performed for this EA through the use of the computer code RADTRAN 4 [SNL, 1992]. RADTRAN 4 contains idealized mathematical models for transportation environments. These models have been formulated to yield conservative estimates (i.e., those that tend to overstate the impact) of integrated population dose in a way that can be supported by available data. For example, RADTRAN 4 estimates that, in the event of an accident, people would not be evacuated for 24 hours. In actuality, people would most likely be evacuated sooner, thereby reducing the time of exposure. The models in RADTRAN 4 do not include features of the transportation environment that either do not affect the calculated risk values or reduce conservatism.

The RADTRAN 4 computer code combines user-determined meteorological, demographic, transportation, packaging, and physical characteristics factors with health physics data to calculate the expected radiological consequence of incident-free and accidental risk of transportation of radioactive material. User-assigned parameters are defined by individual route segment links, for example, ocean passage or highway links between intersections of the various routes taken by the transportation conveyance. Environmental parameters that are quantified using values specific to each transportation link include transport distance, accident rates, and population density. All other environmental parameters, e.g., traffic densities, are left at recommended RADTRAN 4 values to yield conservative results. The reference SNL, 1992, contains details of these default values. Finally, the doses calculated by

RADTRAN are converted to cancer fatality risks using the appropriate dose-risk conversion factor for the exposed population (see Section 6.1.1.).

Input parameters that describe the route and population distribution for the overland transportation segment from the proposed ports of entry to Piketon, Ohio, are contained in the HIGHWAY [ORNL, 1992] computer routing program. The HIGHWAY program provides a flexible tool for predicting and describing highway routes for transporting radioactive materials in the United States. The HIGHWAY data base is essentially a computerized road atlas that currently describes over 240,000 miles of highways. Complete descriptions of all interstate systems and most U.S. highways (except those that parallel nearby interstate highways) are included in the data base. Many of the principal state highways and a number of local and county highways are also identified. The data base also includes locations of nuclear facilities and major airports, including the Portsmouth GDP. Routes are calculated by minimizing a combination of distance and driving time for a highway route between two points. Several routing constraints can be imposed during the calculations.

One of the special features of the HIGHWAY model is its ability to identify routes that maximize use of interstate system highways. This feature allows the user to establish baseline routes for shipments of radioactive materials that conform to DOT routing regulations, which require that interstate system highways be used to the maximum extent possible. This explains why the same major highways would be repeatedly used for shipments of radioactive materials, rather than alternate routes over non-interstate highways. Within the context of risk assessment, these routes should be considered as representative of typical routes that might be used for normal transportation between two points. Specific routes cannot be predicted because factors such as weather, construction, accidents involving other vehicles, and local and state ordinances can change the route that might be used for transportation. Other features of the model include the ability to predict routes that bypass a specific city, town, or highway segment.

Two unique features have been incorporated in HIGHWAY, Version 3.1. The first is the ability to automatically identify alternative routes. Frequently, there are a number of routes between the source and destination that vary slightly in distance and estimated driving time. Most routing models will produce only a single route. With the alternative routing feature, the HIGHWAY program offers a selection of different but nearly equal routes.

The second special feature is the capability to calculate route-specific population density statistics. The population density distribution is calculated for each highway segment in the route and is reported on a state-by-state basis. State borders are treated as nodes in HIGHWAY. The route is always broken into segments at a state border, regardless of whether the code would have otherwise designated a stretch of road intersected by a state border as a single segment. Within a state, route segments are differentiated on the basis of population density and road type. Each internodal segment (i.e., a segment with a node at each end) is broken down into smaller segments identified by population density. Each small segment

is initially classified as belonging to one of twelve "bins" or population-density ranges; these segments are then aggregated to give rural (Bins 1-5), suburban (Bins 6-9), and urban (Bins 10-12) segments. The population density reported for each rural, suburban, or urban segment is the weighted average of the densities in the segments used to generate the aggregate. Thus, each internodal segment becomes up to three aggregated segments representing rural, suburban, and urban population densities from the beginning node to the terminating node. Population densities are determined using 1990 census data and a sophisticated series of mathematical calculations which are detailed in the documentation of HIGHWAY [ORNL, 1992].

Transportation risks were calculated for each segment of the entire shipping campaign of LEU cylinders from St. Petersburg, Russia, to Piketon, Ohio. The first segment is the at-sea transport from St. Petersburg to one of the marine cargo terminals located in one of the proposed ports of entry. The risks associated with the proposed action were calculated by assuming that the Russian LEU would be shipped at two different rates (i.e., Phase 1 and Phase 2). During Phase 1 (FY 94-98), 7 shiploads of UF_6 would annually arrive at one or more of the proposed ports of entry. During Phase 2 (FY 99-13), 19 shiploads per year would annually arrive at one or more of the proposed ports of entry. Each shipload would contain 32 Model 30B cylinders, loaded four cylinders per SEAPAK. The port operations segment calculated the risks of getting the ships alongside the pier, then discharging their cargo. Each marine shipment is followed by eight truck shipments from the marine terminal to Piketon, Ohio. Each individual truck shipment was modeled as carrying four cylinders, or one SEAPAK.

The maritime transportation link between St. Petersburg and the U.S. port of entry was conservatively modeled by including in the analysis three intermediate port calls at U.S. ports before each conveyance vessel reaches one of the proposed ports of entry. (This same assumption is used for the alternative ports considered in Section 6.6.5). These intermediate port calls were modeled with a conservative generic model so that the results would represent the possibility that sea-going vessels might make an intermediate port call at any deep water port. It was not intended that the analysis would model any specific maritime shipping route constrained by specific intermediate port calls or would even imply that any intermediate port calls would in fact occur. The intent was to generate a conservative estimate of maritime risk. (For purposes of the accident risk assessment, the intermediate ports were assumed to be high population density ports.) The distances between the ports of St. Petersburg and the proposed ports of entry were determined using the publication "Distances Between Ports" [DMAHTC, 1991]. Once a shipment was in port, the LEU packages (actually the SEAPAKs loaded with cylinders in their overpacks) would be off-loaded from the ship by port workers and inspected by customs officials, United States Coast Guard personnel, etc. The length of their exposure was estimated at 10 minutes per person per SEAPAK. After

the shipment was off-loaded, it was assumed that it was placed in a secure staging area for up to 24 hours awaiting truck transportation to the Portsmouth GDP.²

Each SEAPAK was assumed to contain four cylinders of UF_6 with a radiation level of 0.5 millirem (mrem)/hr at one meter from the surface of the SEAPAK. This assumption is based on actual measurements of SEAPAKS containing four cylinders of UF_6 at approximately the same assay (i.e., 4 percent) as the proposed shipments. These measurements yielded radiation levels in the range of 0.2 to 0.4 mrem/hr at one meter from the surface of the SEAPAK [Conkel, 1993]. Thus the actual measurements have been conservatively adjusted to the level of 0.5 mrem/hr.³

Port workers and inspectors are not considered as radiation workers as defined by NRC's regulations. Thus, the maximum annual allowable exposure for these personnel would be 100 mrem, the same radiation dose limit established by NRC's regulations to protect individual members of the general public (i.e., this allowable exposure level is less than that allowed for potentially exposed radiation workers) [FR, 1991].

The overland transportation of LEU was modeled by identifying the most direct route from the gate of each marine terminal yard to the nearest interstate highway using detailed city maps. The most direct route generally would minimize the risk. From the city road connection to the interstate system, a representative interstate route to the gate of the Portsmouth GDP in Piketon, Ohio, was developed with the HIGHWAY routing model, as discussed above.

² The proposed action does not include any long-term storage of the SEAPAKS at the marine terminals, or anywhere en route to the Portsmouth GDP. The 24 hour-period for the staging of SEAPAKS was selected because it is possible that on occasion the SEAPAKS will not leave the secure staging area on the same day they arrived, depending on variables such as the time of day the SEAPAKS clear customs. Nonetheless, it is unlikely that the SEAPAKS would remain in the staging area for longer than 24 hours. Indeed, it is likely that the SEAPAKS will usually remain in the staging area for less than 24 hours.

³ In the risk estimate prepared for a prior draft of this EA, RADTRAN applied the 0.5 mrem/hour level to a distance of one meter from the center of the packaging, pursuant to RADTRAN's standard theoretical estimates of radiation levels. This procedure resulted in an overestimation of doses to those handling the cargo because the SEAPAK is 8 feet wide by 8 feet high. Therefore, a point one meter (approximately three feet) from the center would be inside the SEAPAK. This overestimation, resulting from code calculations occurring when the distance from the package is small in comparison to package size, is corrected in this EA to reflect actual measurements. These measurements indicate that the level of radiation is less than 0.5 mrem at one meter from the outer surface of the SEAPAK (approximately seven feet from the center). These adjustments were not included in the risk analysis for a prior draft of this EA (October 1993) or for the October 1993 EA for the Purchase of LEU from the Russian Federation Pursuant to the Agreement Suspending the Antidumping Investigation of Uranium (Suspension Agreement EA) (USEC/EA-93001), but were included in the amended Suspension Agreement EA (November 1993, USEC/EA-93001(A)).

6.2.2 Routine Operations

Transportation health and safety consequences for the sea transit, port operations, and overland transport segments of the proposed action under routine conditions would be very small. During routine operations there would be essentially no impact on the general population as a result of the proposed action. This would also be true of any intermediate port of call.

Marine Environment

Because the proposed action involves ocean transport, the USEC addressed the environmental impacts of this proposed action on the global commons taking into consideration Executive Order 12114.

Informal consultation was conducted with the National Marine Fisheries Service concerning the potential environmental impacts to threatened or endangered species/critical habitats, which may result from the proposed shipments of LEU from Russia. The Service indicated that, under normal transport conditions, shipment of LEU by commercial vessel would be indistinguishable from any other commercial shipment, and that impacts to threatened or endangered species or critical habitat were unlikely (see Section 7.0). Indeed, under routine operations there would be no impact on the marine environment as a result of the proposed action.

Port and Overland

The risk from transportation of the samples taken to verify LEU acceptability, as described in Section 2.1, would be negligible. The sample amounts involved in the proposed action would be considered "limited quantities" which are excepted from most Department of Transportation regulations (except for packaging) due to the negligible risk presented by transportation of these small quantities (see 49 CFR 173.421) [DOT, 1990]. Any doses resulting from shipment of these samples would be extremely small in comparison to those resulting from the proposed action and well within the doses estimated by the NRC's Environmental Assessment NUREG-0170 (see Section 6.5.1.2).

The universe of persons reasonably assumed to be at risk from the radiological impact of routine (incident-free) operations resulting from the proposed action, including the assumptions and conditions used in the risk analysis in this EA, are described in Table 6-4.

Table 6-4. Description of Risk Groups

Risk Group	Description
General Public	General population within 800 meters of the shipment while in transit or during stops, including those sharing the roadway with the shipment
Port Handlers and Inspectors	5 persons at 1 meter from each package for 10 minutes
Other Port Workers	50 persons at 50 meters for 16 hours
Conveyance Crew	Sea - Hold inspectors only ^a Truck - Two persons at 10 meters for duration of overland segment
Storage Personnel	20 persons at 100 meters for 24 hours

- ^a Ship crews, except for hold inspectors, are shielded from packages by the ship's structure and other cargo and receive only extremely small doses during transit.

During incident-free transportation, individuals near the SEAPAKs containing the cylinders filled with LEU would receive low levels of external exposure to radiation (gamma and x-rays) emitted by the LEU. No internal exposures would be received since the UF₆ would be contained within the cylinders. Since some low-level external exposure is unavoidable, the risk of exposure has the same value as the dose received.

The computer code RADTRAN 4 was used to calculate the total incident-free radiological dose and increased latent fatal cancer risk (LCF) for the entire 20-year period of the proposed action.⁴ The LCF risk represents the total increased fatal cancer risk under the proposed action. An LCF is defined as a fatal malignancy that may occur after some latent period, usually 10 or more years, and has a probability of occurrence that increases with dose. The total incident-free radiological dose from all transportation segments for the entire 20-year period of the proposed action as calculated by RADTRAN is presented

⁴ Actual radiation measurements of fully loaded UF₆ cylinders did not detect any radiation above background levels at a distance of 5 meters and greater from the SEAPAK [Conkel, 1993]. These "zero" readings result from radiation levels at those distances being below the lower limit of detection of the instrument. As a result, theoretical calculations in RADTRAN were used to determine potential exposure rates, even though the exposure rates are very small and not measurable using standard radiation survey instruments, at distances between 0.5 and 800 meters from the SEAPAK. These RADTRAN calculations tend to result in conservatism in the doses and LCF risk estimated since, for example, the calculations assume there are no objects between the SEAPAK and the individuals located at various distances from the SEAPAK.

in Table 6-5. The total public person-rem dose is spread out in very small increments over a large potentially exposed population (261,000 people if Hampton Roads would be the port of entry). The large population is obtained by multiplying HIGHWAY population densities (rural, suburban and urban on a state-by-state basis) by the appropriate areas that are 800 meters wide on each side of the representative interstate highway route between the port of entry and the Portsmouth GDP and adding in the figures for the various worker populations listed in Table 6-4. The same methodology was used for each of the proposed ports of entry.

Table 6-5. Total Radiological Incident-Free Risk For Proposed Action

Port of Entry	Transportation Dose Risk (Person-Rems)		Total Risk to Public ¹	
	Sea Transit and Port Operations	Overland Transport	Person-Rems	LCF
Hampton Roads	3.44	4.96	8.40	0.0037
Baltimore	3.48	4.05	7.53	0.0032
Charleston	3.48	4.80	8.27	0.0035
New York	3.43	5.90	9.33	0.0040
Savannah	3.50	5.04	8.54	0.0037
Houston	3.61	9.16	12.77	0.0056
Philadelphia	3.45	5.15	8.60	0.0037

¹ The values presented for each port assume that all shipments in the proposed action pass through that port. In that event, the risk to the public from the proposed action at each of the other ports would be zero.

The estimated maximum exposure to an individual not actively involved in shipping the LEU represents a hypothetical maximum dose that would be received by a specific individual member of the public who lives beside the highway route. The individual is assumed to be exposed to every shipment of the campaign at a distance of 30 meters. The estimated maximum annual exposure to an individual for incident-free overland transportation would occur during the last 15 years of the proposed action, when the greatest quantity of UF₆ would be shipped (FY99-FY13). Each shipment is modeled by RADTRAN as passing by the individual at 24 km/hr (15 miles per hour). The maximum individual annual dose was calculated to be 0.002 (2×10^{-3}) mrem for incident-free operations during the years of the greatest quantity of UF₆ shipments. The assumption employed in this EA was also utilized in the amended Suspension Agreement EA. This maximally exposed member of public would be the same for any port of entry since this person is assumed to be present for all shipments at the same distance from the highway route. The maximum individual dose calculated by RADTRAN can be converted into an estimate of increased lifetime risk of a radiation induced LCF by applying the National Academy of

Science's estimated risk of a radiation induced LCF for the general public: 0.0005 (5×10^{-4} LCFs/person-rem). Thus, the maximum dose calculated by RADTRAN would translate into an increased risk of dying from a latent cancer induced by this proposed action over background (to this hypothetical individual member of the public) of 1 in one billion (0.000000001 or 1×10^{-9}).

Along the transportation corridors that would be used in implementing the proposed action or an alternative involving overland transportation in the United States, the average annual effective dose equivalent for a member of the general population from natural background radiation (including indoor radon) is 300 mrem [NCRP, 1987]. This natural background radiation dose can be compared to the estimated maximum annual individual dose of 0.002 (2×10^{-3}) mrem which would result from the proposed action.

The estimated maximum exposure to a worker represents a hypothetical maximum dose that would be received by a specific worker who inspected/handled one-third of all of SEAPAKs shipped to carry out the proposed action. Because the ships would arrive at all times of the day or night (and any day during the week), it was assumed that the maximally exposed individual worked an eight-hour shift and would be present for one-third of all shipments. It would not be expected, however, that all of the ships transporting the UF_6 would use the same port of entry. Therefore it is conservative to assume that a maximally exposed individual is located in one port through which all of the UF_6 transits. The assumption employed in this EA, that the maximum exposure of any port worker would be limited to one-third of the total proposed shipments, is thus considered to more closely approximate actual conditions than the assumption in an earlier draft of this EA (October 1993), and the original Suspension Agreement EA that a port worker would be exposed to all of the proposed shipments. The assumption employed in this EA was also utilized in the amended Suspension Agreement EA. The maximum annual dose that handlers/inspectors would receive would be 4.1 mrem, or 69 mrem for the entire 20 years of the proposed action. This total program dose translates into an increased fatal cancer risk of 2.8 out of one hundred thousand (0.000028 or 2.8×10^{-5}).

Air

As described in Sections 2.1 and 4.0, a number of HEU and LEU samples would be transported from Russia to the U.S. by air. For the purpose of this assessment, it was assumed that 50 grams of U-235 would be transported in each air shipment. The package containing the uranium samples was assumed to have a maximum dimension of 0.5 m and a dose rate of 0.25 mrem/hr at one meter. Each airplane was also assumed to have three crew members located 20 feet from the package. During flight, the dose rate received by a member of the aircraft crew from the uranium is estimated at 0.01 mrem/hr. The cargo handlers loading or unloading the cargo from the airplanes were estimated to receive 0.2 mrem from each shipment.

The National Council on Radiation Protection and Measurements (NCRP) noted that air travel at an altitude of 39,000 feet gave an enhanced cosmic-ray exposure of 0.5 mrem/hr [NCRP, 1987]. As a result, the aircraft crew would receive 0.5 mrem/hr from cosmic-rays; a substantially larger dose rate than the 0.01 mrem/hr from the uranium.

6.2.3 Accident Conditions

Marine Environment

Because the proposed action involves ocean transport, the USEC addressed the environmental impacts of the proposed action on the global commons taking into consideration Executive Order 12114.

During ocean transport, the most severe accident involving stress to the UF_6 cargo from force would be a ship collision. However, the impact of a ship into another ship at a velocity of 30 km/hr is less severe than the drop test (See Table 6-3) for a Type B package [NAC, 1989]. As a result, it would be unlikely that a significant release of UF_6 would occur during a ship collision.

As discussed in Appendix B, it is extremely unlikely if not impossible for an accident at sea involving collision, fire, or other mishap to result in release of all UF_6 from one or more cylinders due to the size of cargo ships, the protective nature of cargo compartments in a transport ship, the potential that the SEAPAKs would be stored in different holds, and the protective nature of the cylinders and their overpacks (as discussed in Section 6.2). As a result, for purposes of probability analysis, it is assumed that the proposed at-sea shipment of UF_6 would present no increased risk to humans for two reasons. First, an accident at sea (i.e., outside of port areas) would affect only the ship's crew and not members of the general public (in contrast to an accident in port or along an overland transport route). Second, if an accident of sufficient severity to threaten release of all of the contents of one or more of the overpacked cylinders occurred, the risk of fatality to the crew members would be as great from the general severity of the accident (e.g., fire, collision, drowning) as from release of the contents of the cylinders. Thus, the nature of the material in the overpacked cylinders adds no incremental risk of fatality to a crew member above the risk from accident incurred by any ocean cargo transport. It is also extremely unlikely, if not impossible, that the proposed shipments would present any significant risk from an accident to the marine environment, as discussed in the following paragraphs.

In 1984, the French cargo ship Mont-Louis sank after having been involved in a collision with a ferry. The cargo included thirty (30) Type 48Y cylinders of uranium hexafluoride. In view of the nature of the cargo, particularly its value, it was decided to salvage the UF_6 cylinders as quickly as possible and to recover the material. All 30 containers were recovered. They were all intact except one, which had a slight leak in the valve [Ringot, et al., 1987]. It is important to note that the Type 48Y cylinders were

not in overpacks. The Model 30 B cylinders used for the proposed action would be even less prone to failure than the cylinders on the Mont-Louis since the Model 30 B cylinders would be in overpacks.

Moreover, there is no significant risk to the marine environment even in the event that one or more cylinders or one or more SEAPAKs are lost at sea and not retrieved. The oceans contain significant quantities of uranium and its daughter products due to naturally occurring processes (See Section 5.1). As a result, marine organisms are exposed to relatively high levels of background radiation. The cylinders, which contain the UF_6 , and their overpacks are designed, constructed, and tested to withstand a severe collision, as explained above, so that unretrieved cylinders lost as the result of an accident at sea are likely to remain intact. Since uranium has not been found to bioamplify in fish (and only slightly in other marine organisms) in the marine environment, even in the extremely unlikely event that both the overpack and cylinder failed, an accidental release would result in only slight increases in the exposure of marine organisms which tend to be more radiation resistant than terrestrial mammals and which are already exposed to similar concentrations of uranium.

As a result of the large volume of water, the mixing mechanisms within it, the background concentrations of uranium, and the radiation resistance of aquatic organisms, the radiological impact of the very low probability accident releasing uranium into the ocean would be localized and of short duration. Also, any cylinders accidentally lost in the ocean or coastal waters would be retrieved, if at all possible, because of the economic value of the UF_6 . This would practically eliminate the possibility of multiple containers slowly corroding and releasing their contents over time. Even if not retrievable, the impact of a slow release would be even less severe than a catastrophic failure of a cylinder.

The second aspect of a marine accident is the chemical hazard. Uranium hexafluoride (UF_6) reacts with water in an exothermic reaction that releases uranyl fluoride and hydrofluoric acid (HF). The reaction is not explosive. The HF produced would dissolve very quickly in the sea water. When dissolved, the HF dissociates into H^+ and F^- ions. These ions and the UO_2F_2 are the toxicological agents responsible for physiologic effects from a potential release of UF_6 in ocean water. If an instantaneous, complete hydrolysis of the contents of a single cylinder is assumed (highly unlikely; supporting discussion follows), the peak concentrations of H^+ and F^- ions from a total release of UF_6 from a container would be approximately $2 \mu g/l$ at a distance of 100 m. These concentrations are below toxic levels. The uranyl fluoride formed would settle on the sea-bed and slowly dissolve.

The solubility of uranyl fluoride in water at average sea water temperatures is approximately 650 g per kg of water [Linke, 1965]. An instantaneous, complete hydrolysis of the entire contents of a single Model 30B cylinder would produce localized concentrations of uranyl fluoride of approximately 2600 g per kg of water; therefore, the uranyl fluoride would dissolve over an indefinite period of time, depending upon ocean currents. However, if the worst case scenario of instantaneous dissolution of all uranyl

fluoride formed is assumed (while not possible; supporting discussion follows), the peak concentration of uranyl fluoride would be approximately 0.02 mg per kg of water at a distance of 500 m.

If a ship carrying Model 30B cylinders in overpacks containing UF_6 were to sink in an area where recovery was not possible, it is valid to assume that the impact on the marine environment would be minimal for the following reasons:

- While Type B packagings (equivalent to a 30B cylinder in its overpack) have only been immersion-tested to a depth of 15 m (Table 6-3), they are likely to maintain their integrity at much greater depths. Type B plutonium oxide shipping containers, which are less robust than a Model 30B cylinder in a 21PF-1B overpack, have been successfully subjected to a static crush force of 5000 pounds along each of the container's three main axes for a period of five minutes. None of the tested containers leaked [SNL, 1975].
- If the cylinders in their overpacks were to sink to a depth where external pressures could crush the containers, exposure of the solid UF_6 to sea water would be gradual through cracks in the containers, not catastrophic. Without vigorous mixing, hydrolysis of solid UF_6 is very slow. In laboratory experiments where 0.5-1.0 g of solid UF_6 were combined with 50 ml of water, hydrolysis was complete in approximately 10 minutes at room temperature when the reaction vessel was "violently shaken;" however, without shaking, the reaction was still incomplete after 24 hours [Shinohara, et al., 1967]. Based on these data, it is reasonable to assume that the reaction of solid UF_6 with sea water that gradually seeps in through cracks in the cylinder and its overpack would occur over weeks, even months, at a rate that would allow the hydrofluoric acid and the uranyl fluoride to be quickly dispersed to nontoxic levels by ocean currents.
- The total biomass per square meter decreases exponentially with ocean depth (Section 5.1); therefore, at depths where package failure might occur, the amount of flora and fauna potentially exposed to toxic levels of hydrofluoric acid and uranyl fluoride would be minimal.

For these reasons there is no risk of significant injury to the marine environment from UF_6 cylinders which may be lost and not retrieved in the event of an accident at sea.

Port

A port is treated as a maritime link in the RADTRAN code. This link includes a 15 km approach to the port and a stop, with unloading activities, at the port. The accident risk is calculated on the basis of an accident rate per port transit, where actual accident rate data for the port being modeled is used. It is possible to use the accident rate per port transit (as opposed to calculating the risks from accidents during channel transit, dock approach, and unloading at dock) because all accidents are treated conservatively

as occurring at dockside (i.e., dispersion is always over land). The population density of the immediate urban area of the port being modeled is used as the population density under the entire LEU plume footprint out to a distance of 80 km. This extremely conservative assumption tends to overestimate the consequences of an accident and accounts for the reason that port operations present most of the estimated accident risk from the proposed action. Appendix B contains further descriptions of the accidents modeled for the port segment of the proposed action. Table 6-6 shows the accident radiological risks for the proposed ports of entry for the port operations segment for the entire twenty years of the proposed action.

Table 6-6. Port Operations Accident Radiological Risk for the Proposed Action^a

Port of Entry	Risk to Public ^b	
	Person-Rem	LCF
Hampton Roads	43.8	0.022
Baltimore	48.0	0.024
Charleston	48.0	0.024
New York	52.8	0.026
Savannah	42.2	0.021
Houston	42.9	0.021
Philadelphia	46.1	0.023

^a Risk associated with an activity or event is defined as the product of the probability of undesirable outcomes and a numerical quantification of the consequences associated with these outcomes. As such, the units associated with risk estimates are the same as the units associated with the consequences since probability is a unitless quantity.

^b The values presented for each port assume that all shipments in the proposed action pass through that port. In that event, the risk to the public from the proposed action at each of the other ports would be zero.

Overland⁵

The overland transportation accident model in RADTRAN 4 assigns accident probabilities for a set of accident severity categories. The accident severity categories represent the range of credible accident conditions that could be expected to occur in the event of an accident. The least severe accident categories, which are representative of low crush forces on the package, but no fire, are the most probable accident conditions. The most severe credible accident categories, which are representative of

⁵ The risk of fatalities resulting only from increased truck traffic is discussed in Section 6.2.4.

high crush or puncture forces on the package, severe fire, and package failure, are the least probable accident conditions. Accident impacts were calculated for the surrounding population in general using the population density of the area along the road on which the accident was presumed to occur. The population dose was then estimated by assuming that the LEU was dispersed and distributed to all members of the population residing within the entire accident plume footprint out to a distance of 80 km. Distinct population or worker groups were not differentiated for accident impacts. The radiological transportation risk was calculated for the overland transportation segments of the seven proposed ports of entry for the entire twenty years of the proposed action as shown in Table 6-7.

Table 6-7. Overland Transportation Accident Radiological Risk from Port of Entry to Piketon, Ohio, for the Proposed Action^a

Port of Entry	Risk to Public ^b	
	Person-Rem	LCF
Hampton Roads	0.62	0.00031
New York	0.99	0.00049
Charleston	0.49	0.00024
Baltimore	0.61	0.00030
Savannah	0.47	0.00024
Houston	0.96	0.00048
Philadelphia	0.79	0.00039

^a Risk associated with an activity or event is defined as the product of the probability of undesirable outcomes and a numerical quantification of the consequences associated with these outcomes. As such, the units associated with risk estimates are the same as the units associated with the consequences since probability is a unitless quantity.

^b The values presented for each port assume that all shipments in the proposed action pass through that port. In that event, the risk to the public from the proposed action at each of the other ports would be zero.

The chemical effects of a release of UF₆ during transport by truck from the port to the Portsmouth GDP were also assessed even though there has never been an accident, during transport, involving the release of radioactive material from an accident resistant package such as a Model 30B cylinder with overpack [SNL, 1991]. Further, no transportation accidents with fatalities or injuries due to the chemical or radioactive nature of UF₆ have occurred in the last 30 years [Kovac, 1988]. Approximately 650,000

metric tons of UF_6 have been safely shipped to and from the Portsmouth GDP since the beginning of its operation in the mid-1950s through March, 1993 [Donnelly, 1993]. In the past 10 years (1984-1993), 16,311 shipments of low enriched UF_6 (containing 94,360 metric tons uranium) were shipped in the United States without a release of UF_6 [Staggs, 1993]. During the most severe accident in which it is assumed (for purposes of risk analysis) that all cylinders would be subjected to a fire, which converts the solid UF_6 to a gas, the cylinders rupture, and all of the UF_6 is released from all four cylinders on the truck, lethal concentrations of hydrogen fluoride may exist up to 100 ft downwind of the release point. Based on data for spent fuel casks [Wilmot, 1981], and considering that a Type B package is likely to effect a release before a spent fuel cask will effect a release, the probability of the most severe accident (described above, i.e., all of the contents of all four cylinders are released) occurring is estimated at 0.000000065 (6.5×10^{-8}) for the 20-year period of the proposed action, using Hampton Roads as the port of entry for example purposes. Table 6-8 shows the concentrations an individual would be exposed to under this very low probability accident given that the individual is present for exposure to the entire plume of released material. Although the health effect of this very low probability event would be lethal for an individual located within 100 feet of the accident and who is also stationary for the entire duration of the plume (a very unlikely probability), the probability of the event is so low that the risk is minimal. During less severe accidents, the hydrogen fluoride may cause nasal and lung irritation and the uranium may cause renal injury or milder health effects within 800 ft downwind of the release point.

Table 6-8. Integrated Air Concentration of Uranium and Hydrogen Fluoride Under Low Probability Severe Accident Conditions Assuming Exposure to Total Release Plume^a

Distance from Accident	HF Exposure (mg HF/m ³)(min)	U Exposure (mg U/m ³)(min)
100 ft.	120,000	350,000
350 ft.	30,000	88,000
800 ft.	12,000	35,000

^a Note per Figures 6-1 and 6-2, (53,000 mg HF/m³)(min) is the lethal level and (35,000 mg U/m³)(min) is lethal to 50 percent of those exposed.

The conclusion that the consequences of a severe accident (and the risk when taking into account the extremely low probability of a severe accident) would be minimal is consistent with an analysis by the NRC of the impacts of the January 4, 1986 accident, in which an overfilled 14-ton UF_6 cylinder ruptured while being heated in a steam autoclave at the Sequoyah Fuel Corporation site in Gore, Oklahoma. The rupture resulted in about half of the contents of the cylinder, or 6.7 tonnes, being deposited off-site because of wind dispersal. Extensive studies have concluded that the only measurable risk from the accident was to workers in the immediate vicinity of the ruptured cylinder. The NRC concluded that,

although it was possible that some members of the public suffered from short-term changes in kidney function caused by the chemical toxicity of uranium, the radiation exposure from the accident did not perceptibly increase the individual cancer risk for the population [NRC, 1986]. The cleanup process for that accident, as for any accident, would be sufficiently rigorous and overseen by regulatory authorities that it is expected that there would be no substantial and long-lasting impact on the environment.

Total Accident Risks

The total accident radiological risk is a summation of the port operations and overland transport segments of the proposed action. Table 6-9 shows the total accident risk.

Table 6-9. Total Accident Radiological Risks to the Public for the Entire 20 Years of the Proposed Action

Port of Entry	Transportation Segment Risk to Public (in Person-Rem)		Total Risk to Public ^a	
	Port Operations	Overland Transport	Person-Rem ^b	LCF
Hampton Roads	43.8	0.62	44.5	0.022
Baltimore	48.0	0.61	48.6	0.024
Charleston	48.0	0.49	48.5	0.024
New York	52.8	0.99	53.8	0.027
Savannah	42.2	0.47	42.7	0.021
Houston	42.9	0.96	43.8	0.022
Philadelphia	46.1	0.79	46.9	0.023

^a The values presented for each port assume that all shipments in the proposed action pass through that port. In that event, the risk to the public from the proposed action at each of the other ports would be zero.

^b Total person-rem is the rounded sum of incident-free and accident dose risks.

Air

As described in Sections 2.1 and 4.0, a number of HEU and LEU samples would be transported by air from Russia to the United States. For the purpose of this assessment, each aircraft was assumed to be carrying 50 grams of U-235 as cargo.

In the event of an aircraft crash which released all 50 grams of the U-235 (from the HEU and LEU samples) being transported, the maximum dose to an individual located 360 feet from the crash was estimated as 10 mrem or a latent cancer fatality risk of 0.000005 (5×10^{-6}). At 1200 feet the dose was estimated as 2 mrem or a latent cancer fatality risk of 0.000001 (1×10^{-6}). Assuming air shipment miles in the U.S. for both transparency and product quality samples would be similar to the truck miles under the proposed action, the probability of an air accident would be 0.004 (4 out of one thousand) [DOT, 1993] for the entire 20-year purchase program. If the assumption is made that, in the event of an aircraft crash carrying uranium samples an individual is located 1200 feet from the crash, then the risk for the entire 20-year period of the proposed action of an accident resulting in a latent cancer fatality is estimated at 0.000000004 (4×10^{-9}) or 4 out of a billion. In comparison, there would be an expected 1.35 deaths resulting from that same aircraft accident from causes other than exposure to radiation [DOT, 1992].

6.2.4 Total Radiological Risks

The total radiological risks associated with the transportation of Russian LEU from St. Petersburg to Piketon, Ohio, are shown in Table 6-10. Incident-free dose estimates differentiate between workers and the general public for calculations of LCF risk. Workers are considered to be part of the general public when accident risks are determined. Therefore, the risk conversion factor of 0.0005 (5×10^{-4}) LCF/person-rem, described in section 6.1.1, was applied to the calculation of accident risks. As shown by Table 6-10, the total transportation risk (accident and incident-free) for the entire 20 years of the proposed action, assuming for example Hampton Roads as the port of entry for all shipments, is 0.026 (2.6×10^{-2}) LCFs (i.e., out of the entire exposed population from Hampton Roads to Piketon, Ohio, assuming this port of entry, there is a 2.6 out of 100 chance that one person out of the 261,000 people exposed would die of cancer resulting from the proposed action).

Table 6-10. Total Radiological Risks of Transportation for Proposed Action^{a,b}

Port of Entry	Sum of Total Accident Risk and Incident-Free Risk Estimates for Proposed Action	
	Person-Rem	LCF
Hampton Roads	52.9	0.026
Baltimore	56.1	0.028
Charleston	56.8	0.028
New York	63.1	0.031
Savannah	51.3	0.025
Houston	56.6	0.027
Philadelphia	55.5	0.027

^a The values presented for each port assume that all shipments in the proposed action pass through that port. In that event, the risk to the public from the proposed action at each of the other ports would be zero.

^b These figures reflect the modifications to RADTRAN 4 and the radiological impact calculations described in Section 6.2.1, with respect to using actual radiation level measurements instead of calculated levels for the incident-free handling of the SEAPAKs. For this reason, the figures differ from the calculation of total radiological risks (which proposed Hampton Roads as the port of entry) included in Table 6-8 ("Total Radiological Risks for Transportation for Proposed Action") of an earlier draft EA (October 1993) for this proposed action.

The total transportation risk, expressed in terms of LCFs, was calculated in a risk analysis which included numerous conservative assumptions of events which are highly unlikely to occur. For example, the incident-free annual exposure risk assumes extremely unlikely coincidences such as exposure of the same worker to one-third of all shipments in the proposed action or exposure of an individual member of the public to every highway shipment of the LEU. In addition, most of the calculated total LCF risk derives from the probability analysis of potential accidents, including the most severe overland transport accident in which it is assumed that, for analytical purposes, all four cylinders on a truck release 100 percent of their contents. As noted above, the probability of this event occurring is conservatively estimated as 6.5 chances out of one hundred million (using Hampton Roads as the port of entry for example purposes). Moreover, the risk analysis includes accident scenarios which are virtually impossible. For example, the most severe overland transport accident assumes the airborne release of the contents of all four cylinders for analytical purposes. In reality, the cylinders will be transported in overpacks contained in a SEAPAK and the UF₆ is likely to remain in solid form even if all three forms of packaging fail in such an accident.

Accordingly, the total transportation risk analysis does not represent a prediction that a particular rate of fatal cancer incidence would be generated by the proposed action. In the absence of any transport accident resulting in the release of the cylinders' contents—an event which is extremely unlikely and which has never before occurred—the risk of contracting a fatal cancer from incident-free transport, even with conservative assumptions, is about four times lower than the estimated risk for accidental release (see Section 6.2.2).

Since the 1 tonne HEU demonstration shipment (about 45 tonnes of UF_6), that may be implemented prior to start-up of full shipments under the proposed action is part of the 500 tonnes of HEU that would be imported under the proposed action, the impacts and consequences of the demonstration shipment have already been included in the foregoing impact assessments.

In addition to the radiological risks of the proposed action, there is the risk of fatalities resulting from the additional truck traffic carrying the UF_6 . The National Transportation Board estimates that for every 100 million truck miles there will be 1.5 deaths due to accidents involving trucks [DOT, 1992]. On this basis, using Hampton Roads as an example, there would be an expected 0.02 deaths from the additional truck traffic resulting from implementation of the proposed action over 20 years. In comparison, the radiological risk from truck transportation accidents for the general public from the proposed action is 0.00031 latent cancer fatalities (See Table 6-7). The routinely encountered truck fatality risk is therefore approximately one hundred times greater than the accident radiological risk.

6.3 POTENTIAL IMPACT AT THE PORTSMOUTH GDP

The proposed action would not require any new process activities at the Portsmouth GDP. However, there could be an increase in UF_6 sampling, cylinder handling, and cylinder docking activities. In this section the potential incremental impacts resulting from the proposed action on GDP process activities are examined. Table 6-11 shows the input and output streams for the GDP complex if 4.4 percent U-235 product were produced during the two phases of the proposed action.

Table 6-11. Impact of the Russian LEU Purchase Program on U.S. GDP Production Over the Next 20 Years

WITHOUT OVERFEEDING:							
RUSSIAN LEU	FEED SUPPLIED	AMOUNT PRODUCED (4.4%)	FEED NOT USED	OPERATING TAILS ASSAY	GDP PRODUCTION	POWER REQUIREMENTS	DU ¹ PRODUCED
(MTU)	(MTU)	(MTU)	(MTU)		(MSWU)	(MW)	(MTU)
Base	18,291	1,913	-----	0.280%	12.0	3,200	16,378
305	18,291	1,608	2,920	0.280%	10.1	2,700	13,763
915	18,291	998	8,751	0.280%	6.3	1,700	8,542
WITH OVERFEEDING:							
RUSSIAN LEU	FEED SUPPLIED	AMOUNT PRODUCED (4.4%)	FEED NOT USED	OPERATING TAILS ASSAY	GDP PRODUCTION	POWER REQUIREMENTS	DU PRODUCED
(MTU)	(MTU)	(MTU)	(MTU)		(MSWU)	(MW)	(MTU)
Base	18,291	1,913	All feed supplied is used as overfeed	0.280%	12.0	3,200	16,378
305	18,291	1,608		0.355%	8.8	2,400	16,683
915	18,291	998		0.498%	4.4	1,200	17,293

¹ DU = Depleted Uranium

6.3.1 Impact on GDP Production

As discussed in Section 2.0, Russia is expected to blend HEU with 1.5 percent U-235 to produce 4.4 percent U-235 LEU. Approximately 305 MTU/yr of Russian LEU would be available for the first five years, and 915 MTU/yr for the last 15 years of the proposed contract.

If the USEC is not able to increase market share, a smaller quantity of LEU would be produced at the GDPs to meet the demand for 4.4 percent U-235 of 1,913 MTU/yr. Producing less LEU means that the amounts of feed and electricity required by the GDPs would be reduced. However, as provided in their enrichment services contracts, the GDP customers would continue to deliver the same amount of natural uranium feed, that is, 18,291 MTU/yr to obtain the 1,913 MTU/yr of LEU they desire. The excess natural uranium feed could be used to overfeed the GDPs. This would further reduce the amount of separative work the GDPs must produce and therefore, the amount of electricity required. Table 6-11 summarizes the impact on GDP production, power, and feed from implementing the proposed action if market share does not increase. The table shows the impact under both overfeeding and no-overfeeding situations. It should be recognized that if all of the excess feed during the last 15 years of the Agreement is overfed, the ASTM specification of 10,000 micrograms of U-234 per gram of U-235 would be slightly exceeded. This would require either an agreement with fuel fabricators to accept the product, or a change in the ASTM specifications. However, material specifications may limit the tails assay to about 0.35 percent. Under this limit on the tails assay, it would not be possible to overfeed all excess feed delivered during the years when 915 MTU of Russian LEU would be received at the GDPs.

The Russian LEU has substantial SWU value, as shown in Table 6-11. At levels of 30 MTU/yr of HEU, the enrichment work required by the diffusion plants to meet demand would be low enough that either GDP alone could meet the demand. As a result, even though the minimum demand of about 7 MSWU/yr to keep both GDPs operational from an economic standpoint would be met, there would be sufficient SWU capacity at one plant to meet forecasted demand. The socioeconomic impact of closing one of the GDPs has been previously assessed in DOE's "Socioeconomic Assessment: Partial Closure of the Paducah Uranium Enrichment Facility" [DOE, 1985c] and "Socioeconomic Assessment: Partial Closure of the Portsmouth Uranium Enrichment Facility," [DOE, 1985d]. These documents are incorporated by reference into this EA.

The assessments predict the worst-case socioeconomic impacts of plant closure on the Portsmouth and Paducah communities. However, the assessments make no allowances for personnel retention involving reassignment and retraining, if necessary, for future decontamination and decommissioning (D&D) or environmental restoration activities at the GDP. It is likely that some involuntary layoffs would be required if a decision to close a GDP were to be made. As reported by Grady et al. [Grady, 1987], experience with the closure of the Oak Ridge Uranium Enrichment Facility in 1985 verified to some extent the predictions in "Socioeconomic Assessment: Partial Closure of the Oak Ridge Uranium

Enrichment Facility" [DOE, 1985b]. The long-term socioeconomic impacts predicted in the assessment were partially offset by the ability of the other DOE facilities in Oak Ridge to hire personnel released from the facility. However, about 150 highly skilled specialized personnel could not be placed in other positions within the DOE Oak Ridge complex. Personnel with experience or education to immediately switch from uranium production-related activities to environmental or waste management activities have largely been placed in other positions. A number of ex-Oak Ridge uranium enrichment personnel now work in positions related to D&D and environmental remediation at the plant. These projects are expected to last for many years.

While the impact of closure of the Oak Ridge Uranium Enrichment Facility was moderated by the factors described, socioeconomic impacts from closure of either the Portsmouth or Paducah GDP would not be as easily mitigated. Neither Portsmouth nor Paducah have co-located DOE facilities to which personnel can transfer, nor do the local areas have large industrial bases which could easily absorb displaced workers from the GDP. As a result, the closure studies for Portsmouth and Paducah would probably be more accurate than the Oak Ridge assessment, which overestimated the impact of closure. A plant closure was estimated to result in a 11.3 and 16.7 percent increase in unemployment in Paducah and Portsmouth, respectively [Grady, 1987].

6.3.2 Impact on Natural Uranium Feed Inventory

Since current USEC enrichment services contracts provide for the enrichment services customers to deliver feed to the GDPs, the entire amount of feed resulting from the delivery of the Russian LEU may not be able to be overfed (see Section 6.3.1). As a result, an increasing stockpile of natural uranium feed could occur. However, natural uranium feed is a valuable resource that has been utilized in the past at the GDPs by operating the plants at a higher tails assay to reduce power costs.

If the purchase of Russian LEU results solely in additions to the inventory of natural uranium feed at the plants, there would be little physical impact other than additional cylinders placed in existing holding facilities. As shown in Table 6-11, if none of the excess natural uranium feed is used to overfeed the GDPs, 2,920 metric tons per year of natural uranium could accumulate during the FY94 through FY98 period, and 8,751 metric tons per year of feed could accumulate during the period FY99 through FY13, for a total of about 146,000 metric tons of natural uranium. This amount of natural uranium feed would be stored in about 23,000 large steel cylinders that hold about ten tons of UF_6 each (the same type of cylinders discussed in section 6.3.3 below). Compared with the 40,000 cylinders currently stored at the GDPs and because of the large unused areas at the GDP sites, the storage of the additional 23,000 cylinders would not significantly impact the sites.

If the decision were made not to place in inventory the excess feed which cannot be overfed to the plants, the USEC may seek to sell the uranium feed in the international market or make arrangements to sell the

LEU (which has the effect of selling the natural uranium component). The proceeds from the sale would help to offset the cost of operating the USEC plants. As shown in Table 6-11, as a limiting situation, if none of the excess natural uranium feed is used to overfeed the GDPs, 2,920 metric tons per year of natural uranium could be disposed of on the international market during FY94-FY98, and 8,751 metric tons per year of feed could be sold from FY99-FY13. These quantities of natural uranium are equivalent to about 8 million pounds of uranium oxide per year for the FY94-FY98 period, and about 23 million pounds of uranium oxide per year from FY99-FY13.

As shown in Section 5.6.1, the total U.S. production of uranium oxide during the period FY94-FY98 is expected to average about 8 million pounds per year, and for the period FY99 through FY05 (the last year of the DOE projection) is expected average about 10 million pounds per year [DOE/EIA, 1991b]. The total uranium oxide requirement for U.S. nuclear power plants for the period FY94-FY98 is expected to average about 45 million pounds per year, and for FY99-FY13 from 32 to 60 million pounds per year [DOE/EIA, 1992]. If all of the excess equivalent uranium oxide were sold on a prorated basis to the domestic and foreign producers who are expected to supply U.S. nuclear power plants, domestic producers would experience about a 20 percent reduction in deliveries during the FY94-FY98 period and about a 40 to 70 percent reduction during the FY99-FY13 period. These reductions would be especially painful for the domestic uranium production industry, and it is likely that some of the few suppliers remaining would go out of business, especially during the beginning of the next century. Since the equivalent uranium oxide is in the form of UF_6 , such sales of UF_6 could affect the profits of the one U.S. conversion company, Allied Signal.

Another option for the use of the natural uranium component would utilize a provision of the proposed contract for the purchase of LEU derived from the dismantlement of Russian nuclear weapons that provides for the possible return of the natural uranium component, i.e., the 1.5 percent assay U-235 blended with the HEU to product the 4.4 percent U-235 LEU, to Russia. If the USEC did not order the natural uranium component, Russia would have the option of the return of all or part of the natural uranium component in accordance with mutually satisfactory arrangements being negotiated. Such arrangements could include provisions in order to assist the domestic uranium production industry.

6.3.3 Impact on Depleted Uranium Storage

Depleted uranium at the Portsmouth and Paducah GDPs is stored as UF_6 in 14-ton cylinders. The Portsmouth GDP currently stores about 14,000 cylinders of depleted uranium on site, with an additional 1,300 cylinders being added each year. The Paducah GDP currently stores about 25,000 cylinders, with 1,200 more cylinders being added each year. The cylinders are stored in the open air, and are stacked in rows, two high, on special storage pads. Atmospheric corrosion on the cylinders is extremely slight, and an extensive test program started in the early 1970s indicates that the oldest of the cylinders at the GDPs are expected to have a remaining service life until at least 2020, with the newest cylinders having

a service life of more than 70 years. The wall thickness for the oldest of the cylinders at the GDPs could approach 1/4-inch, the minimum thickness specified for cylinders in service, by the year 2020. However, cylinders that have a wall thickness of 1/4-inch will still provide a considerable measure of protection for the depleted uranium in the cylinders.

Based on an exhaustive inspection of all of the depleted uranium cylinders at the two GDPs, two cylinders at the Portsmouth plant were found to have a small hole in their sides. The hole in each of the cylinders was caused when a lifting lug from an adjacent cylinder bumped against the cylinder during the stacking operation. Because a relatively insoluble plug is formed when the UF_6 reacts with the moisture in the air, one of the cylinders was determined to have lost essentially no uranium, while the other cylinder was determined to have released less than 0.5 percent of the uranium in the cylinder to the environment, with no measurable impact. These two cylinders have been emptied and are undergoing examination to provide additional information on the ability to continue safely storing depleted uranium. All cylinders at the two plants are carefully inspected each year to assure that no new leaks have developed. In addition, improved stacking procedures have been instituted at the two plants to eliminate the possibility that a depleted uranium storage cylinder will be damaged in the future.

The proposed action would have a small impact on the number of cylinders storing depleted uranium if all excess feed were used as overfeed. As shown in Table 6-11, the import of the 305 MTU of HEU converted to LEU would result in an increase from 16,378 MTU to 16,683 MTU in the depleted uranium (DU) produced during Phase 1. This additional 305 MTU of DU would result annually in an additional 37 cylinders over the expected 2,000-2,500 cylinders to be added to storage annually during 1994-1998. During Phase 2 (1999-2013), the additional 915 MTU of DU would result in an additional 111 cylinders being annually added to storage. As a result, the proposed action would be expected to have minimal impact on DU storage.

6.3.4 Impact on Health, Safety and the Environment at Portsmouth GDP

Uranium hexafluoride is the most abundant hazardous material on-site at the Portsmouth GDP. Aside from nuclear considerations, UF_6 can be handled safely in essentially the same manner as any other corrosive and/or toxic chemical by employing procedures developed to accommodate the characteristics of the material. The level of routine exposure to chemicals is regulated by the Occupational Safety and Health Act (OSHA) standards with which the Portsmouth GDP is required to comply. Since no new processes or activities at the Portsmouth GDP are expected to result from the proposed action, the level of routine exposure to chemicals for workers is not expected to either increase or decrease as a result of the proposed action.

Because no new processes or activities at the Portsmouth GDP are expected to result from the proposed action, the level of routine radiological exposure for workers and the public is not expected to either increase or decrease as a result of the proposed action.

Historically, there have been no lethal exposures or significant injuries from accidents involving either toxic materials or radiation in about 115 plant-years of operating experience at the gaseous diffusion plants in the United States [Martin Marietta, 1991]. The proposed action would essentially require the GDPs to continue to operate under current plant conditions with the possible exceptions of lower power consumption (from overfeeding), more product inventory, and a slight increase in the number of depleted uranium cylinders placed in inventory during a twelve-month period in 1993-1994. These changes are well within the conditions under which the Portsmouth GDP can be operated safely, as described in the Final Safety Analysis Reports for the Portsmouth GDP [Martin Marietta, 1985].

6.4 ECONOMIC CONSEQUENCES

This assessment addresses the potential economic impacts on the nuclear fuel cycle industries, enrichment services and the gaseous diffusion plants, electric utilities, and the proposed ports of entry resulting from the importation into the U.S. of low enriched uranium (LEU) from dismantled nuclear weapons in Russia.

6.4.1 Economic Impact on Nuclear Fuel Cycle Industries

The basic element of this part of the analysis was to select two economic and political scenarios with which to compare the impact resulting from the proposed action. The scenarios reflect the dynamic status of the nuclear fuel cycle markets under the No Action alternative in which the U.S. does not sign a contract to purchase Russian LEU derived from HEU. Two scenarios were formulated because the nuclear fuel cycle markets and industries are in a state of flux due in part to political and economic changes that have occurred in the Commonwealth of Independent States (CIS). The CIS is becoming much more active in the nuclear fuel cycle markets than was the former Soviet Union. The two scenarios used are:

- Scenario 1: The LEU market is maintained at its current status without conversion of HEU to LEU in Russia for shipment to the U.S. (No Conversion)
- Scenario 2: HEU is converted to LEU in Russia and is sold by the Russians for resale or directly to the world market. (No U.S. purchase contract for LEU derived from 500 tonnes of HEU.)

Scenario 1 is the least likely response on the part of the Russians if the proposed action to purchase Russian LEU derived from HEU were not carried out. The Russian Federation has considerable HEU

resources which represent hard-currency value. It is extremely unlikely that all of the HEU recovered from dismantled nuclear weapons would be simply put in storage in Russia if the U.S. fails to sign the proposed contract.

Scenario 2 is the likely response of the Russian Federation if the proposed contract were not signed. The Russians have already been seeking additional markets and avenues for utilizing the SWU value in their HEU. It is likely the Russians would convert and blend large quantities of their HEU and then attempt to sell the LEU on the world market. An Agreement suspending the Antidumping Investigation on Uranium from the Russian Federation (Suspension Agreement) signed by the U.S. and the Russian Federation on October 16, 1992, limits the natural and enriched uranium sold by the Russian Federation in the U.S. until the year 2000. The quantities of material which may be sold under this Agreement rise as the price of uranium increases.

6.4.1.1 Uranium Mining and Milling Industry

Scenario 1—Proposed Action Versus the Situation as it Exists Today (No Conversion of HEU to LEU)

If the USEC were to not purchase the Russian LEU and the Russians did not convert and blend the HEU to LEU, the USEC would continue to receive from the utilities the feed to produce their desired enriched product, and there would be no impact on the uranium mining and milling industry. Under the proposed action, the Russian LEU could annually displace about eight million pounds of uranium production during the first five years of deliveries under the proposed contract. This represents about 19 percent of U.S. utility requirements. The impact this material would have on employment would depend on how the USEC utilizes the excess feed material. If the USEC were to overfeed uranium at the GDPs there would be no impact on domestic uranium production. If the USEC were to relieve its domestic utility customers of eight million pounds of their uranium oxide delivery obligations during the first five years of the agreement (present contracts do not provide for such relief) or sell the excess feed, the impact would be felt more heavily on foreign producers, since more than 70 percent of the uranium oxide used by U.S. utilities comes from imports. If the eight million pounds of uranium oxide were prorated between foreign and domestic producers, domestic producers would experience about a 20 percent reduction in deliveries, which could be painful in an industry the Secretary of Energy has already determined to be non-viable for eight consecutive years (see Section 6.3.2).

During the succeeding 15-year period when the quantity of the Russian LEU is tripled under the proposed action, the 24 million pounds per year of uranium oxide production that could be displaced by the Russian LEU represents about a 40 to 70 percent reduction in domestic production during that period (see Section 6.3.2). If the USEC were able to overfeed the GDPs (see Section 6.3.1), there would be little or no

impact on domestic uranium production. However, it is unlikely that USEC would be able to overfeed all of the 24 million pounds per year of displaced uranium oxide production.

Scenario 2—Proposed Action Versus Availability of LEU from Russian HEU on the World Market (No U.S. Purchase Contract for LEU Derived from 500 Tonnes of HEU)

If the USEC were to not purchase the Russian LEU and the Russians converted and blended the HEU to LEU and then sold the LEU on the world market, the price and demand for uranium mining and milling services would decrease. However, since the U.S. uranium production industry would be insulated to some degree from any negative effect on the price of uranium ore while the Suspension Agreement is in effect, the no-purchase alternative would not have a major impact on U.S. production during this decade. On the other hand, the USEC purchase of Russian LEU would tend to result in an increase in the uranium oxide price during this decade, if it is assumed that the excess feed delivered to the GDPs would be overfed and that the Russians would otherwise sell the converted LEU in the market. However, if USEC does not overfeed the excess uranium oxide, the impact on the uranium production industry would approach that of Scenario 1.

The situation is different when the Suspension Agreement ends and the upward impact on the price stemming from the U.S. purchase is estimated to be greater, as the amounts of LEU (and hence uranium oxide equivalent of the LEU) are greater. Presuming that large amounts of this LEU could be sold in the U.S. market after the year 2000 without the USEC purchase of Russian LEU, this would depress the price and supplant U.S. uranium production. In this case, the USEC purchase would have the effect of maintaining U.S. uranium oxide production and employment at about the current levels, as long as the USEC does not sell the LEU on the open market.

6.4.1.2 Uranium Conversion Industry

Scenario 1—Proposed Action Versus the Situation as it Exists Today (No Conversion of HEU to LEU)

If the USEC were to not purchase the Russian LEU and the Russians did not convert and blend the HEU to LEU, the USEC would continue to receive from the utilities the converted oxide feed to produce their desired enriched product, and there would be no impact on the uranium conversion industry. If the USEC were to purchase the Russian LEU and relieve utilities of their obligation to deliver feed to the GDPs or sell the excess feed, the Russian LEU could displace about eight million pounds of uranium oxide, currently converted annually, during the first five years of the proposed contract. The negative impact on the conversion industry could increase during the succeeding fifteen-year period when the quantity of the Russian LEU is tripled from the initial amount imported. However, if the USEC were

to overfeed the GDPs, there would be no impact on the conversion industry. As noted in section 6.4.1.1, USEC may not be able to overfeed all of the displaced uranium oxide production.

Scenario 2—Proposed Action Versus Availability of LEU from Russian HEU on the World Market (No U.S. Purchase Contract for LEU Derived from 500 Tonnes of HEU)

A USEC purchase of Russian LEU would be expected to protect U.S. uranium conversion activities from low-cost UF_6 which would be available in the world market if the Russians converted and sold their HEU. To the extent that USEC overfeeds or otherwise withholds the displaced uranium oxide production from the world market, the period of time in which the purchase would most strongly protect the domestic conversion industry is the period of time that the U.S. industry would be most insulated from lower international prices, due to both the Suspension Agreement and existing term contracts. It is still possible that the U.S. purchase would continue to have a protective influence on domestic uranium conversion after the year 2000, although it would not be as pronounced as during the pre-2001 period. In the worst case where USEC would sell all displaced uranium oxide production, the impact would be similar to Scenario 1.

6.4.1.3 Fuel Fabrication Industry

This is the portion of the fuel cycle that would be least affected by the proposed purchase of Russian LEU from a market standpoint, if it is affected at all. The purchase would not change the amount of fuel that would need to be fabricated, and is not expected to change the price of fabrication.

6.4.2 Economic Impact on the Enrichment Industry (the U.S. Gaseous Diffusion Plants)

Scenario 1—Proposed Action Versus the Situation as it Exists Today (No Conversion of HEU to LEU)

If the USEC were to not purchase the Russian LEU and the Russians did not convert and blend the HEU to LEU, the USEC would continue to meet anticipated demand from utilities for about 12 MSWU per year from the GDPs. If the USEC were to purchase the Russian LEU and use the excess natural UF_6 feed delivered by utilities to overfeed the enrichment plants during each year of the first five years of the agreement, the impact would be felt primarily in the reduced electric energy consumed by the plants. The combination of producing less LEU and overfeeding could result in electric energy reductions of about 16 percent for the period 1994-1998. There would be no loss of employment at the gaseous diffusion plants.

The USEC, under the terms of the Energy Policy Act of 1992, is under an obligated lease from DOE, whereby the GDPs are available to the USEC for a certain period of time. As noted before, present

commitments for deliveries of enriched uranium are at a level of roughly 12 million SWUs per year. This is enough to support continued operation of both Portsmouth and Paducah GDPs. However, the need to commit to long-term contracts for operation of both GDPs remains in question, whether or not the USEC acquires LEU from Russian HEU.

To some extent, the availability of the Russian LEU will promote the continued operation of the GDPs, in that the availability of a supply in addition to that available from the GDPs provides the USEC with additional flexibility. A decision not to extend leases for both GDPs may be appropriate, after determining the best mix of operations and transfers to meet the Congressionally-mandated responsibilities of the USEC. That choice will be determined more by the ability of the USEC to maintain market share than by any other business factor. The availability of the Russian LEU, as opposed to Scenario 2, below, is believed to improve the opportunities for the USEC to maintain and increase market share.

Scenario 2—Proposed Action Versus Availability of LEU from Russian HEU on the World Market
(No U.S. Purchase Contract for LEU Derived from 500 Tonnes of HEU)

The international price of enrichment would be depressed if the U.S. did not purchase LEU from the Russians and the Russians sold at least some of this material on the international market. These low market prices would impair the USEC's ability to capture future business. Unfilled enrichment requirements on the part of utilities increase greatly after the year 2000, the time when the U.S.-Russian Federation Suspension Agreement ends. At this point, the additional Russian LEU could be sold to U.S. purchasers, where most of the USEC's business is located. Studies have shown that the nuclear fuel procurement policies of U.S. utilities are price sensitive—more price sensitive than their counterparts overseas—and U.S. utilities would be likely to buy large quantities of LEU, especially on the spot market. Thus, the U.S. market would presumably be the most susceptible to sales of Russian LEU. It is quite certain that under this scenario, the USEC's market share would decline, and this decline would be sufficient to induce the closure of an enrichment plant. Thus, not only would production fall, but so would market share, price, and revenues.

Using this example as a basis of comparison, the USEC purchase of Russian LEU would benefit the U.S. enrichment industry. While it cannot be guaranteed that this purchase would keep both enrichment plants operating, it would allow the USEC to maintain (or expand) its market share, which would result in higher enrichment prices, and increased revenues and the continuing viability of the enrichment enterprise. The USEC, by purchasing the Russian LEU, could more reasonably manage the impact on production employment, than if this LEU were sold by Russia elsewhere in the market.

6.4.3 Economic Impact on the Electric Utility Industry

The Russian LEU, particularly the larger amounts to be received during the last 15 years of the contract, could substantially reduce the amount of electricity required for the GDPs. The Russian LEU represents about 16 percent of current SWU production during the first five years and 48 percent during the succeeding fifteen years. The reduced electricity consumption would have no impact on GDP plant employment.

Under the terms of the contract between the DOE and EEI for the Paducah GDP, either party has the right to reduce the contract unilaterally by 10 percent per year or to terminate the contract entirely with a 5-year notice. Under terms of the contract between DOE and OVEC for the Portsmouth GDP, DOE has the right to reduce contract demand or to terminate the contract unilaterally with a 3-year notice. DOE also has the right to request movement of power to Paducah if it is no longer needed at Portsmouth or for OVEC to use its best efforts to dispose of power no longer needed by DOE.

The reduction in power consumption under overfeeding and non-overfeeding scenarios would require DOE to implement the terms of their contracts with either or both EEI and OVEC. The high percentage of nonfirm power used at Paducah provides an opportunity to reduce nonfirm power and enact a smaller change in the power provided under the terms of the DOE-EEI contract.

Implementing the terms of the DOE and utility contracts could have a minor impact on utilities and the coal mining activities which provide coal to the three plants providing firm power to the GDPs. The power currently produced and consumed by the GDPs is relatively inexpensive. Thus, to the extent that it is below the cost of other sources, the surplus power could be sold to one or more utilities in the region, displacing other more expensive power. Such actions would simply shift the effects of reduced production and consumption to other utilities and fuel producing states and counties. The new source of power on the grid could also mean that planned power plants would not be needed in the short term to meet increasing demands for electricity as the U.S. population increases.

6.4.4 Economic Impact on Proposed Ports of Entry

Each of the ports proposed as a port of entry for the Russian LEU to be shipped under the proposed action is an established port with large quantities of cargo flowing through it. The proposed quantity of Russian LEU traveling through any of the proposed ports would be extremely small compared to the present volume of cargo handled, as discussed in Section 5.2. An additional seven shiploads (assuming 32 cylinders of UF_6 per ship) per year over the existing port traffic could arrive at the port during the first five years of the purchase program (Phase 1), given the assumption of 451 t/yr of UF_6 . The current port traffic could increase by 19 shiploads per year for the subsequent 15 years (Phase 2), given the assumption of 1,353 t/yr of UF_6 . Based on this information, the proposed action would be expected to

represent an increase in the range of 0.0036 percent (Port of Houston) to 0.052 percent (Port of Charleston) in total foreign cargo imports at the proposed ports during the period of greatest shipments. The likelihood that the shipments of LEU would arrive at more than one of the ports means that the percentage increase in total cargo tonnage would be even smaller. No special port facilities or special operations would be required at any of the proposed ports to handle the Russian LEU shipments.

6.5 CUMULATIVE IMPACTS

This section describes the cumulative impacts resulting from the proposed action.

Since accident risk calculations in RADTRAN do not distinguish between port workers and the general public, it is not possible to determine any one individual's (port worker, truck driver, member of the general public, etc.) risk from an accident. In the event of an accident (fire, crane failure, explosion, collision, etc.) the potential radiological consequences would vary and may even be masked by more severe impacts (e.g., burning and crushing) depending on the individual's location and activity at the time of the accident. As a result, radiological accident risk to an individual is not estimated and only non-accident (incident-free) radiological doses are assessed for cumulative impacts.

6.5.1 Cumulative Transportation Impacts

The following sections discuss the cumulative radiological impact that the proposed action would have on the workers and the general public who potentially would be exposed as a result of the proposed action. The first section discusses the Negligible Individual Dose (NID) recommendation of the National Council on Radiation Protection and Measurements (NCRP). The second section describes the results of the "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes," NUREG-0170 [NRC, 1977]. The third section discusses the doses received from the proposed action in relation to natural background, the NID, and NUREG-0170. The final section summarizes the cumulative effect evaluation.

6.5.1.1 Negligible Individual Dose

The National Council on Radiation Protection and Measurements (NCRP) recommends that an annual effective dose equivalent of 1 mrem (0.01mSv) or less be considered a Negligible Individual Dose (NID) per source or practice [NCRP, 1993]. The NID is defined by the NCRP as the "level of effective dose [equivalent] that can be dismissed" or as the level of average annual excess risk of fatal health effects attributable to radiation below which efforts to reduce radiation or exposure to the individual is unwarranted. The dismissal of risk was considered in relation to: (1) magnitude of dose, (2) difficulty in detection and measurement of dose and health effects, (3) natural risk for the same health effects, (4) estimated risk for the mean and variance of natural background radiation exposure levels, (5) risk to

which people are accustomed, and (6) perception of, and behavioral response to, risk levels [NCRP, 1993].

6.5.1.2 NUREG-0170 and Population Exposures

The proposed action is similar to LEU importation, transportation, and processing activities already taking place in the same locations and along the same routes. The transportation of radioactive materials and shipments of UF_6 to support the fuel cycle, in particular, were assessed in the "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes, NUREG-0170" [NRC, 1977]. This Environmental Statement considered the risk of transporting millions of packages of radioactive materials along transportation corridors, such as the ones which would be used for the proposed action, and determined that the total annual incident-free and accident risk was minimal. The most recent study of the number of radioactive material shipments indicates no substantial change in the number of shipments or in their characteristics that would invalidate the general result of NUREG-0170 [SNL, 1985]. Since the transportation of the Russian LEU would meet the same regulations assessed in NUREG-0170, the risk is still negligible for all cumulative transportation activities. For individuals residing near principal transportation routes, NUREG-0170 estimated that the average annual individual effective dose equivalent from radioactive material transportation activities was about 0.09 mrem. This average annual individual dose remains valid for considering the cumulative impacts associated with the proposed action.

6.5.1.3 Estimated Doses for the Proposed Action

Calculations have been carried out to estimate the maximum occupational and public doses associated with the transportation of the Russian LEU. The calculated maximum annual exposure a member of the public would receive from routine transportation activities associated with the proposed action is 0.002 (2×10^{-3}) mrem during the last fifteen years of the proposed action. (See Section 6.2.2.) This dose is small in comparison to the NID and to the individual dose estimated in NUREG-0170, which is the accumulation over all radioactive material shipments. Along the transportation corridors that would be used in implementing the proposed action, the average annual effective dose equivalent for a member of the general population from natural background radiation is 300 mrem [NCRP, 1987]. This natural background radiation dose can also be compared to the estimated maximum annual individual dose of 0.002 mrem that would result from the proposed action.

The maximum exposure for a worker involved in transporting the Russian LEU is predicted to result from activities associated with the unloading of the Russian LEU in port and its inspection and preparation for truck shipment to the Portsmouth GDP. Of the various types of personnel working closely with the SEAPAKs containing the overpacks and cylinders filled with the UF_6 , the maximum exposure time per SEAPAK per person is conservatively assumed as 10 minutes [Weiner and Neuhauser, 1992]. If the

same worker were to be exposed to one-third of all cylinders shipped in seven different ships, the total annual individual dose would be approximately 1.4 mrem. Each of the ports proposed as a port of entry routinely receives commercial shipments of uranium and other radioactive materials, as discussed in Section 5.2. Based on these other import/export activities, the dose an individual port worker could receive was assessed as described in Appendix C.

An additional source of radiation exposure could be from shipments resulting from the purchase of Russian LEU under the Agreement Suspending the Antidumping Investigation on Uranium from the Russian Federation (Suspension Agreement). Shipments of LEU under the proposed 20-year program would not be expected to begin until mid to late 1994 and would not occur concurrently with Suspension Agreement shipments. However, since shipments of the weapons-derived LEU may occur during calendar year 1994 and shipment under the Suspension Agreement would take place earlier in calendar year 1994, the annual dose calculated for this period, i.e., calendar year 1994, considers shipments from both sources. The proposed 20-year contract would provide for 305 metric tons of LEU to be shipped each year during the first 5 years of the contract, and 915 tons in each of the last 15 years. This EA uses the 305-ton amount for the cumulative impact analysis because any overlap of the proposed action with the Suspension Agreement LEU purchase would occur during the first year of the proposed 20-year contract. The cumulative impact analysis in a prior draft EA for the proposed action (October 1993) used the amount of 915 tons of weapons-derived LEU, representing one of the last 15 years of that proposed contract⁶.

A final source of radiation exposure could be from DOE's proposal to import approximately 700 elements of foreign research reactor spent nuclear fuel to provide urgent relief to certain foreign research reactors, to the extent such shipments overlap with the proposed action at any of the proposed ports. If the same individuals were present for one-third of all shipments under the proposed action during one of the first five years of the contract, one-third of all commercial shipments of radioactive material shipped during a twelve month period, all shipments of the urgent relief foreign research reactor fuel⁷, and one-third of the LEU shipments under the Suspension Agreement, the annual cumulative dose for the proposed ports of entry is shown in Table 6-12. As can be seen in Table 6-12, the cumulative dose is small for all ports of entry and well below the regulatory limit of 100 mrem/yr established by NRC regulations to protect a member of the general public [FR, 1991].

⁶ If the volume of weapons-derived LEU to be shipped in 1994 appears to exceed 305 MTU, USEC is committed to reanalyzing the cumulative impacts of those shipments combined with the proposed action, in an additional amended EA for the antidumping suspension agreement shipments.

⁷ It is assumed that Coast Guard or other type of inspection personnel would inspect each shipment of spent nuclear fuel, and that the eight-hour shift assumption (See Appendix C) would not apply. Accordingly, it is conservatively assumed that the maximum-exposed port worker would be Coast Guard or other type of inspection personnel exposed to all the proposed spent nuclear fuel shipments.

**Table 6-12. Cumulative Individual Annual Radiation Dose for Maximally Exposed Individuals in Proposed Ports of Entry^a
(First Five Years of Proposed Action)**

Port of Entry	Dose from Port Activity (mrem)				Total Annual Individual Dose
	Proposed Action	Commercial Shipments	Suspension Agreement	Foreign Reactor Spent Nuclear Fuel	
Hampton Roads	1.4	4.2	0.9	8.0	14.5
Baltimore	1.4	2.0	0.9	NA(A)	4.3
Charleston	1.4	0.3	NA(B)	8.0	9.7
New York	1.4	10.2	0.9	NA(A)	12.5
Savannah	1.4	3.4	NA(B)	8.0	12.8
Houston	1.4	1.7	NA(B)	NA(A)	3.1
Philadelphia	1.4	0.1	0.9	NA(A)	2.4

^a The values presented for each port assume that all shipments in the proposed action pass through that port. In that event, the risk to the public from the proposed action at each of the other ports would be zero.

NA(A) = not applicable since foreign research reactor spent nuclear fuel has not been proposed for shipment through this port.

NA(B) = not applicable since LEU was not proposed for shipment through this port.

For the last 15 years of the proposed action, the cumulative dose calculation must be changed. First, the Suspension Agreement shipments will have ended. Secondly, the quantities of LEU supplied under this proposed activity would increase three-fold. If the same port worker were to be exposed to one-third of all 19 shiploads per year of the Russian LEU, during the period of greatest shipment (Phase 2), the annual dose would be approximately 4.1 mrem. If the same individuals were present for one-third of all shipments under the proposed action during Phase 2 and one-third of all commercial shipments of radioactive material shipped during a 12-month period, the annual cumulative dose for the proposed ports of entry is shown in Table 6-12A. As can be seen in Table 6-12A, the cumulative dose is small for all proposed ports of entry and well below the regulatory limit of 100 mrem/yr established by NRC regulations to protect a member of the general public [FR, 1991].

Table 6-12A: Cumulative Individual Annual Radiation Dose for Maximally Exposed Individuals in Proposed Ports of Entry* (Last Fifteen Years of Proposed Action)

	Dose from Port Activity (mrem)		
Port of Entry	Proposed Action	Commercial Shipments	Total Annual Individual Dose
Hampton Roads	4.1	4.2	8.3
Baltimore	4.1	2.0	6.1
Charleston	4.1	0.3	4.4
New York	4.1	10.2	14.3
Savannah	4.1	3.4	7.5
Houston	4.1	1.7	5.8
Philadelphia	4.1	0.1	4.2

- * The values presented for each port assume that all shipments in the proposed action pass through that port. In that event, the risk to the public from the proposed action at each of the other ports would be zero.

The figures included in Tables 6-12 and 6-12A reflect the modifications to input into RADTRAN 4 and the radiological impact calculations described in Section 6.2.1, with respect to incident-free radiation levels of the SEAPAKs, and the assumption described in Section 6.2.2 that port workers would be exposed to a maximum of one third of the total proposed shipments and one third of commercial shipments of radioactive materials. In addition, Table 6-12 reflects the volume of Russian LEU to be shipped in the first year of the 20-year contract, as explained above. The figures in Table 6-12 also include the proposed shipment of foreign reactor spent nuclear fuel. For these reasons, the figures in Tables 6-12 and 6-12A differ from the calculations of cumulative maximum individual doses in Section 6.5.1.3 of a prior draft EA (October 1993) for the proposed action.

In addition to the urgent relief foreign reactor spent nuclear fuel importation discussed above, DOE may also import approximately 15,000 elements of foreign research reactor spent nuclear fuel over a period of up to 15 years. It is possible that such imports could overlap with the proposed action, depending on the timing and ports of entry for any such DOE proposal. However, at this time the schedule, volume, and ports of entry for any such proposal are unknown. Therefore, a cumulative impacts risk analysis

including this potential long-term importation cannot be performed in the same manner as has been performed for commercial shipments of other nuclear products, Suspension Agreement shipments of LEU, and urgent relief shipments of foreign reactor spent nuclear fuel. Nonetheless, it is likely that the potential import of 15,000 elements would involve an insignificant risk to port workers even if such imports overlap with the proposed action at the proposed ports. Assuming, for purposes of analysis, that the additional spent nuclear fuel elements are imported over a 15-year period at a constant rate (i.e., 1,000 elements per year), this would likely result in no more than 11.5 additional mrem of exposure, if all such shipments came through the same port and the same port worker were exposed to every shipment. This additional exposure would not exceed the 100 mrem NRC standard even if added to the cumulative impacts analyzed above and summarized in Tables 6-12 and 6-12A.

Finally, the Russian Federation and other nations may possess additional HEU which the United States may attempt to purchase in the future. Analysis of any potential cumulative impacts from such purchases is impossible at this time because the amount of material, the timing of delivery, the potential ports of entry, and even the nature of the material (i.e., importation as HEU or as LEU) is unknown.

6.5.1.4 Summary of Cumulative Transportation Effect Evaluation

The analysis performed for NUREG-0170 includes shipments of UF_6 to and from the Portsmouth GDP. As a result, the doses to the general public that would result from the proposed action are incorporated in NUREG's estimated average individual dose of 0.09 mrem. The maximum annual incremental dose of 0.002 (2×10^{-3}) mrem for a member of the public from routine activities associated with the transportation of the Russian LEU would be well below the NID of 1 mrem and a small part of NUREG 0170's estimated average dose for all radioactive material shipments in the United States. This would still be true if the 0.00032 (3.2×10^{-4}) mrem calculated maximum annual exposure a member of the public would receive from an overlap of the proposed action with the Suspension Agreement shipments of the Russian LEU were included.

6.5.2 Cumulative Economic Impacts

As shown in the analyses in Section 6.4, the overall economic impacts from the proposed action would be minimal. The amount of LEU involved in the proposed action could appreciably affect the USEC's current inventory of LEU, and the operation of the GDPs as discussed in Section 6.3. Other activities, such as the purchase of Russian LEU under the Suspension Agreement, involve sufficiently low quantities of uranium that these activities have little additional impact when considered in conjunction with the proposed action. A separate Environmental Assessment for the Suspension Agreement purchase has been prepared.

The results of the economic impact analyses lead to these conclusions:

- Impacts of the proposed action on uranium mining and milling, conversion, and fabrication industries are expected to be minimal, assuming the USEC overfeeds the GDPs.
- Impacts on the Portsmouth Gaseous Diffusion Plant (employment about 2,630) or the Paducah Gaseous Diffusion Plant (employment about 1,830) and surrounding communities could be substantial from an economic standpoint if a GDP were closed due to a decreased need for enrichment services. A plant closure was estimated to result in a 11.3 and 16.7 percent increase in unemployment in the Paducah and Portsmouth locales, respectively [Grady, 1987].
- Impacts on the electric utilities would result if DOE implemented the terms of existing contracts between itself and either or both EEI and OVEC regarding reduction in contract demands. The impacts are expected to be minimal since the utilities should be able to sell the relatively inexpensive power elsewhere on the national electric grid network.
- Impacts on the proposed ports and surrounding communities would be minimal.

6.6 ENVIRONMENTAL CONSEQUENCES OF ALTERNATIVES

The following paragraphs briefly summarize the potential transportation risks and economic impacts of the six alternatives to the proposed action.

6.6.1 No Action

As discussed in Section 2.2.1, no action means that the U.S. would not sign the contract with the Russian Federation to purchase LEU derived from Russian HEU over a 20-year period. The consequence of this alternative would be that the objectives of the government-to-government agreement to arrange for the safe and prompt disposition for peaceful purposes of HEU extracted from dismantling the former Soviet Union's nuclear arsenal would not be fulfilled by the proposed action. These objectives relate to non-proliferation, support of a new Russian Federation market economy, environmental cleanup in Russia, and conversion of Russian nuclear weapons to nuclear energy for peaceful purposes. The no action alternative would present no increased transportation risk. In terms of economic effects, the no action alternative would likely have a negative impact on U.S. nuclear service industries.

6.6.2 Receipt at the Paducah Gaseous Diffusion Plant

The Paducah GDP is not currently authorized to handle UF_6 with an assay greater than 2 percent U-235. As a result, the Russian LEU currently cannot be received at the Paducah GDP. In mid-1994 when the Paducah GDP is expected to be authorized to process UF_6 with an assay of up to five percent U-235, there would be no difference in the economic impacts of this alternative versus the proposed action.

Since the majority of the transportation risk results from port operations, there is little difference in the transportation risks for the Paducah GDP as the final destination versus the Portsmouth GDP for truck or rail modes of transportation, as shown in Table 6-13, using Hampton Roads, for example, as the proposed port of entry. Since the majority of transportation risk results from port operations, the similarity in risk between the Paducah and Portsmouth GDPs as the final destination would also hold true at the proposed ports other than Hampton Roads. The dose for the maximally exposed worker or member of the general public would be the same for either GDP for overland shipment by truck or rail.

Table 6-13. Comparison of Transportation Risk for the Two Gaseous Diffusion Plants for the Entire 20-Year Proposed Purchase Program (Person-Rem)

	Truck Transport		Rail Transport	
	Incident-Free	Accident	Incident-Free	Accident
Paducah GDP	9.9	44.6	7.5	52.2
Portsmouth GDP	8.4	44.5	6.3	48.1

All segments of transportation (at-sea, port operations, and overland shipments) are included in these estimates.

6.6.3 Receipt at Fuel Fabricators, Domestic or Abroad

The likelihood of transporting the UF_6 obtained from Russia directly to the fuel fabricators is limited because of product quality considerations, as discussed in Section 2.2.2. However, if the UF_6 were sent directly to a fuel fabricator, the economic considerations would be expected to be similar to those of the proposed action.

The transportation risks of this alternative would be essentially the same or slightly reduced if the UF_6 were sent to the U.S. fuel fabricators directly from Russia. As discussed in Section 5.6.4, there are five fuel fabricators in the United States. They are: Westinghouse in Columbia, South Carolina; Babcock & Wilcox in Lynchburg, Virginia; General Electric in Wilmington, North Carolina; ABB-Combustion in Hematite, Missouri; and Siemens in Richland, Washington (although Babcock & Wilcox does not receive UF_6 from the USEC). Since Westinghouse, Babcock & Wilcox, and General Electric are in the eastern United States, the transportation distances would be about 25 to 50 percent shorter than shipping the UF_6 to Piketon, Ohio and then to the fuel fabricators. In these situations, the transportation risk would be reduced only slightly, since most of the risk associated with transportation comes from port operations, which are the same regardless of the ultimate destination of the UF_6 (see Section 6.2). If the shipments of UF_6 were sent directly to ABB-Combustion or Siemens, the transportation risk would be essentially the same since the direct distance to Hematite, Missouri or Richland, Washington is essentially the same as the distance to Piketon, Ohio and then from Piketon to Hematite, Missouri or Richland, Washington.

The transportation risks of this alternative would be slightly reduced if the UF_6 were sent directly to fuel fabricators abroad. The fuel fabricators used by utilities that obtain their enrichment services from the USEC are located in Japan, South Korea, Germany, the United Kingdom, France, Spain, and Sweden. For the fuel fabricators located in the Far East, the transportation of the UF_6 across Russia and then across the Sea of Japan is less than half of the transportation distance across the Atlantic Ocean and to Piketon, Ohio, and then from Piketon, Ohio, to a West Coast seaport and then across the Pacific Ocean to a fuel fabricator. Likewise, for fuel fabricators located in Europe, the transportation of the UF_6 directly within Europe is less than 20 percent of the transportation distance across the Atlantic Ocean and to Piketon, Ohio and then from Piketon, Ohio back across the Atlantic Ocean to the fuel fabricator.

6.6.4 Optional Transport Mode to the United States

Historically, large quantities of UF_6 have not been shipped by air because of the excessive costs in comparison to shipment by ocean-going freighter. The advantage in speed provided by air shipment has never overcome the extra costs. While unlikely, if the air option were selected, there would have to be additional considerations of route, air terminal and package selection. For example, the Model 30B cylinders in their overpacks, while accident resistant, are much more likely to fail in an air accident than in an accident involving trucks or ships. Additionally, the forces involved in an air accident may result in a greater dispersal of the LEU in the environment. However, the probability of an air accident is about twenty times less than the probability of a truck accident on a per mile basis [DOT, 1992]. As a result, the risk of an air accident, where risk is the product of probability and consequence, is about the same as the risk of a truck accident.

6.6.5 Transportation of LEU from Russia through Several Alternative Ports of Entry to Piketon, Ohio

Table 6-14 compares the potential transportation related doses (incident free and accident) calculated by RADTRAN for the entire 20 years of the proposed action based on the port of entry. The transportation doses include the at-sea, port operations, and overland truck transport segments of the proposed action. As can be seen from the table, there are no major differences in the doses, or their associated cancer risks, with respect to any ports of entry. The anticipated increase in port traffic would not be expected to cause any large economic or environmental impacts at the various ports.

It should be noted that the ports evaluated in Table 6-14 represent the probable upper bounds of estimated risk from two perspectives. First, from the perspective of total transport risk (incident-free and accident), Oakland, California, represents the highest estimated risk from any potentially foreseeable commercial port in the United States, assuming overland transport to Piketon, Ohio, based on distance and population density. Second, Hampton Roads represents the highest volume of commercial shipments of nuclear material (based on weight) and the Port of New York and New Jersey represents the highest volume

Table 6-14. Comparison of Incident-Free and Accident Radiological Risk for the Proposed Action Based on Port of Entry^a

Marine Terminal	Transportation Dose Risk ^b - Person-Rems		Total Person-Rems ^c	Total LCFs ^d
	Incident-Free	Accident		
Hampton Roads, VA	8.4	44.5	52.9	0.026
Baltimore, MD	7.5	48.6	56.1	0.028
Elizabeth, NJ	8.6	53.7	62.3	0.030
Philadelphia, PA	8.6	46.9	55.5	0.027
Charleston, SC	8.3	48.5	56.8	0.028
Jacksonville, FL	9.3	42.8	52.1	0.025
Morehead City, NC	8.8	46.8	55.6	0.027
Fernandina Beach, FL	8.5	40.3	46.8	0.024
Port of New York-New Jersey	9.3	53.8	63.1	0.031
Houston, TX	12.8	43.8	56.6	0.027
Providence, RI	10.9	49.8	60.6	0.030
Oakland, CA	21.6	46.2	67.8	0.033
Savannah, GA	8.5	42.7	51.3	0.025

^a The values presented for each port assume that all shipments in the proposed action pass through that port. In that event, the risk to the public from the proposed action at each of the other ports would be zero.

^b Transportation Dose Risk includes at-sea, port operations, and overland transport segments of the proposed action.

^c Total Person-Rems is the rounded sum of incident-free and accident dose risks.

^d LCF = Latent Cancer Fatality

(based on number of packages), for the period August 1992 - July 1993, of any commercial port in the United States. Thus, the risk analysis in this EA should effectively encompass all commercial ports because the total estimated risk should be no higher at any port not listed in Table 6-14. Nonetheless, Tables 6-10 and 6-14 demonstrate that the total estimated risk of the proposed action is negligible at each of the ports (proposed and alternatives) and that there is no significant difference in comparative risks among the ports.

6.6.6 Transport of LEU within the United States by Rail

Under this alternative, once the UF_6 would arrive at the port of entry, the UF_6 cylinders would be transported by rail to the Portsmouth GDP. (The risk assessment methodology used to calculate rail transportation risks is described in Appendix A.) Since rail shipment is an unlikely alternative, only four ports were assessed for the rail option: Hampton Roads, Virginia; Elizabeth, New Jersey; Charleston, South Carolina; and Morehead City, North Carolina. These ports were chosen to represent a range of low to high-density populations. The maritime and port operations segments of the rail alternative are assumed to be the same as those for a truck shipment (see Section 6.2.1). Once in port, the SEAPAKs would be loaded onto rail cars and transported to the Portsmouth GDP. Table 6-15 compares the risks of the rail alternative for the four ports.

As shown by Table 6-15, the comparative total radiological risk for rail transport versus truck is essentially the same for the two modes of overland transport from each of these selected ports. For example, using Hampton Roads as the port of entry, the maximum individual public dose calculated by RADTRAN for the entire shipment activity where the overland transport segment is by rail is 0.00071 mrem (7.1×10^{-4} mrem) during Phase 1 (FY94-98) and 0.002 mrem (2.0×10^{-3} mrem) during Phase 2 (FY99-13). The total radiological incident-free population dose would be 6.3 person-rem and a risk of approximately 0.0028 (2.8×10^{-3}) LCFs. A total of approximately 224,000 people (again, assuming Hampton Roads) are assumed to receive very small increments of this population dose over the 20-year period of the proposed action. The accident risk is 48.1 person-rem or 0.024 LCFs. For these reasons, it is assumed that the comparative risk for rail transport is indistinguishable from truck transport regardless of the port of entry and that this result would hold true for entry through New York-New Jersey, Philadelphia, Houston, Savannah, and Baltimore as well. The economic impacts of this alternative would be the same as those that would result from the proposed action.

**Table 6-15: Total Transport Radiological Risk Assuming Rail Transport
From Selected Ports of Entry for Entire
20 Year Shipping Campaign**

Port of Entry	Transportation Dose Risk Person-Rems		Risk to Public ¹	
	Incident-Free	Accident	Total Person-Rems	Total LCFS
Hampton Roads	6.3	48.1	54.4	0.027
Elizabeth, NJ	7.3	62.9	70.2	0.035
Charleston	6.6	51.5	58.1	0.029
Morehead City	6.6	50.5	57.0	0.028

¹ The values presented for each port assume that all shipments in the proposed action pass through that port. In that event, the risk to the public from the proposed action at each of the other ports would be zero.

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SECTION 8.0

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LIST OF REFERENCES

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Cherry, R.D. and Heyraud, M., 1982, "Evidence of High Natural Radiation Doses in Certain Mid-Water Ocean Organisms," *Science*, 218, 54-56.

Cherry, R.D. and Shannon, L.V., 1974, "The Alpha Radioactivity of Marine Organisms," *Atomic Energy Reviews*, 12, 3-45.

Conkel, M., 1993, "Shipment Radiation Readings," Transmittal from Conkel, Portsmouth GDP to N. Haberman, DOE/NE-35.

Construction Engineering Research Laboratory (CERL), 1990, "Global Commons Environmental Assessment," U.S. Army Corps of Engineers, Champaign, IL.

Council on Environmental Quality (CEQ), 1978, "Regulations on Implementing NEPA Procedures, Part 1500-1508," 43 FR 55990, Washington, D.C.

Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC), 1991, "Distances Between Ports," Pub. 151.

DOE. See U.S. Department of Energy.

Donnelly, R.G., April 29, 1993, "UF₆ Shipments," Letter from Donnelly, Portsmouth GDP Plant Manager to E.W. Gillespie, DOE Site Manager.

DOT. See U.S. Department of Transportation.

Energy Research and Development Administration (ERDA), 1977, "Final Environmental Impact Statement, Portsmouth Gaseous Diffusion Plant Site, Piketon, Ohio," Washington, D.C.

FR. See U.S. Federal Register.

Grady, S., Braid, R., Bradburg, J., Kerley, C., 1987, "Socioeconomic Assessment of Plant Closure: Three Case Studies of Large Manufacturing Facilities," Environmental Impact Assessment Review, 7:151-165.

Hessler, R.R. and Sanders, H.L., 1967, "Faunal Diversity in the Deep-Sea," *Deep Sea Resources*, 14, 65-78.

International Atomic Energy Agency (IAEA), 1976, "Effects of Ionizing Radiation on Aquatic Organisms and Ecosystems," Technical Report Series Number 172, Vienna.

International Atomic Energy Agency (IAEA), 1985, "Sediment K_ds and Concentration Factors for Radionuclides in the Marine Environment," Technical Report Series Number 247, Vienna.

International Atomic Energy Agency (IAEA), 1990, "Regulations for the Safe Transport of Radioactive Material," Safety Series No. 6.

International Atomic Energy Agency (IAEA), 1991, "Interim Guidance on the Safe Transport of Uranium Hexafluoride," IAEA-TECDOC-608, Vienna.

Journal of Commerce (JoC), 1993, Piers Imports and Exports Database Journal of Commerce, New York, New York.

Kovac, F.M., 1988, "Need for Improved UF₆ Handling and Transportation Practice," Conference Proceedings from "Uranium Hexafluoride -- Safe Handling, Processing, and Transporting," May 24-26, 1988.

Linke, W.F., 1965, "Solubilities of Inorganic and Metal Organic Compounds," Vol. II, 4th ed.

Longenecker, J.R., 1991, "Increased Competition and New Technology. Market Trends in Uranium Enrichment for the 1990s and Beyond," in Transactions of the American Nuclear Society, ed. Irene O. Macke, American Nuclear Society, La Grange Park, Illinois.

Manning, W.F., 1986, "Action Description Memorandum (ADM) for Line-Item Projects, Paducah Gaseous Diffusion Plant (PGDP)," Memorandum dated March 5, 1986 to J. Longenecker, Deputy Assistant Secretary for Uranium Enrichment.

Martin Marietta, 1985, "Final Safety Analysis Report," Portsmouth Gaseous Diffusion Plant, GAT/GDP-1073.

Martin Marietta, 1991, "Portsmouth Gaseous Diffusion Plant Fact Sheet," Piketon, Ohio.

Maryland Port Authority (MPA), 1992, "Foreign Commerce Statistical Report," Baltimore, Maryland.

The Merck Index, 1983, 10th ed. Merck Co. Inc., Rahway, New Jersey.

National Academy of Sciences (NAS), 1971, Radioactivity in the Marine Environment, Washington, D.C.

National Academy of Science/National Research Council (NAS/NRC), 1990, "Health Effects of Exposure to Low Levels of Ionizing Radiation," BEIR V, National Academy Press, Washington, D.C.

National Council on Radiation Protection and Measurements (NCRP), 1987, NCRP Report No. 93, "Ionizing Radiation Exposure of the Population of the United States."

National Council on Radiation Protection and Measurements (NCRP), 1991, NCRP Report No. 109, "Effects of Ionizing Radiation on Aquatic Organisms," Bethesda, MD.

National Council on Radiation Protection and Measurements (NCRP), 1993, NCRP Report No. 116, "Limitation of Exposure to Ionizing Radiation."

National Institute on Occupational Safety and Health (NIOSH), 1990, Pocket Guide to Chemical Hazards, 1990, Publication No. 90-117, National Academy Press, Washington, D.C.

Needler, G.T. and Templeton, W.L., 1981, "Radioactive Waste: The Need to Calculate an Oceanic Capacity," *Oceanus*, 24, 6067.

NRC. See Nuclear Regulatory Commission.

Nuclear Assurance Corporation (NAC), 1989, "Sea Transportation Safety Analysis Report," Norcross, Georgia.

Nuclear Energy Agency (NEA), Office of Economic Cooperation and Development, 1988, "Dispersal of Radionuclides in the Oceans: Models, Data Sets and Regional Descriptions," NEA/OECD, Paris.

Oak Ridge National Laboratory (ORNL), 1992, "HIGHWAY 3.1 - An Enhanced Highway Routing Model: Program Description, Methodology, and Revised User's Manual," ORNL/TM-12124, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Oak Ridge Operations (ORO), 1991, "Uranium Hexafluoride: A Manual of Good Handling Practices," ORO-651 (Rev. 6), DE91015811, Contract No. DE-AC05-86OR21644, Analysis Corporation, Oak Ridge, Tennessee.

Pickard, G.L., 1979, Descriptive Physical Oceanography, 3d ed., Pergamon Press.

Port of Houston (PoH), 1993, "Facts About the Port of Houston," Houston, Texas.

Rice, A.L., 1978, "Radioactive Waste Disposal and Deep Sea Biology," *Oceanol. Acta*, 1, 483-491.

Ringot, C., Devillers, C., and Warniez, P., 1987, "L'Accident Du Mont-Louis Et La Securite Nucleaire," IAEA-SM-286/182, PATRAM-86, Vienna.

Sandia National Laboratories, (SNL), Albuquerque, 1975, "Final Report on Special Tests of Plutonium Oxide Shipping Containers to FAA Flight Recorder Survivability Standards," McWhirter, M., Brooks, R.O., Stomp, J.M. and Dillingham, L.A., SAND75-0446, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories, (SNL), Albuquerque, 1985, "Transport of Radioactive Material in the United States: Results of a Survey to Determine the Magnitude of Domestic, Unclassified Shipments of Radioactive Materials," SAND84-7174, Menlo Park, CA.

Sandia National Laboratories, (SNL), Albuquerque, 1991, "Transportation Accidents/Incidents Involving Radioactive Materials (1971-1991)," Cashwell, C.E. and McClure, J.D., SAND91-2767C, TTC1141, Contract No. DE-AC04-76DP00789, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories (SNL) Albuquerque, 1992, "RADTRAN 4: Volume 3, User Guide," Neuhauser, K.S. and Kanipe, F.L., SAND89-2370, Sandia National Laboratories, Albuquerque, New Mexico.

Sax, N.I. and Lewis, R.J., 1987, "Hazardous Chemical Desk Reference," Van Norstrand Reinhold Co., New York, New York.

Shinohara, H., Izawa, K., Tsujimura, S. and Motojima, K., 1967, "Determination of Hydrogen Fluoride and Uranium (III) in Crude UF₆ by Hydrolysis and Potentiometric Titration," *J. Nuc. Sci. and Tech* 4 (9), pp 482-487.

SRI International, April 1985, "Transport of Radioactive Material in the United States: Results of a Survey to Determine the Magnitude and Characteristics of Domestic Unclassified Shipments of Radioactive Materials," Javitz, H.S., Lyman, T.R., Maxwell, C., Myers, E.L., Thompson, C.R., SAND84-7174, Contractor Report, Sandia National Laboratories, Albuquerque, New Mexico.

Staggs, J., 1993, "Low Enriched Uranium Shipments in the United States, "Correspondence on September 7, 1993 between J. Staggs, U.S. DOE, NE-32, and C. Massey, Sandia National Laboratories.

Steele, J.H., Barrett, J.R. and Worthington, L.V., 1962, "Deep Currents South of Iceland," *Deep-Sea Resources*, 9, 465-474.

Swallow, J.C. and Worthington, L.V., 1960, "Deep Currents in the Labrador Sea," *Deep-Sea Resources*, 16, 77-84.

U.S. Bureau of the Census (USBC), 1988, County and City Data Book 1988, U.S. Government Printing Office, Washington, D.C.

U.S. Bureau of the Census (USBC), 1991, Selected Population and Housing Characteristics: 1990, U.S. Department of Commerce, Washington, D.C.

U.S. Coast Guard, March 7, 1985, "Supervision and Monitoring of Radioactive Cargo Operations," Marine Safety Office (MSO) Instruction 16616.4, Norfolk, VA.

U.S. Department of Energy (DOE), 1985a, "Paducah Gaseous Diffusion Plant Final Safety Analysis Report."

U.S. Department of Energy (DOE), 1985c, "Socioeconomic Assessment Partial Closure of the Paducah Uranium Enrichment Facility," DOE/OR/208337-T5, U.S. Department of Energy, Oak Ridge, Tennessee.

U.S. Department of Energy (DOE), 1985d, "Socioeconomic Assessment: Partial Closure of the Portsmouth Uranium Enrichment Facility," DOE/OR/20837-T6, U.S. Department of Energy, Oak Ridge, Tennessee.

U.S. Department of Energy (DOE), 1989 "Physical Protection of Special Nuclear Material and Vital Equipment," DOE Order 5632.2A, Change 1, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE), 1993, "Control and Accountability of Nuclear Materials," DOE Order 5633.3A, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy/Energy Information Administration, (DOE/EIA), 1991a, "Domestic Uranium Mining and Milling Industry 1990: Viability Assessment," U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy/Energy Information Administration, (DOE/EIA), 1991b, "Uranium Industry Annual 1991," U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy/Energy Information Administration, (DOE/EIA), 1992, "World Nuclear Capacity and Fuel Cycle Requirements 1992," U.S. Department of Energy, Washington, D.C.

U.S. Department of Transportation (DOT), 1990, 49 CFR 171-177, Subchapter C, Hazardous Materials Regulations, Washington, D.C.

U.S. Department of Transportation (DOT), 1992, "National Transportation Statistics, Annual Report," DOT -VNTSC-RSPA-92-1, Washington, D.C.

U.S. Enrichment Corporation (USEC), 1993, "Environmental Assessment for the Purchase of Low Enriched Uranium from the Russian Federation Pursuant to the Agreement Suspending the Antidumping Investigation on Uranium," USEC/EA-93001, Washington, D.C.

U.S. Federal Register, January 5, 1981, "Final Guide for Implementation of Executive Order 12114," 46 FR 1007, Washington D.C.

U.S. Federal Register (FR), May 21, 1991, "Standards for Protection Against Radiation; Final Rule," U.S. Nuclear Regulatory Commission, Title 10, Part 20 et al, Washington, D.C.

U.S. Federal Register (FR), May 19, 1993, "Designated Critical Habitat: Northern Right Whale," Proposed Rule, National Oceanic and Atmospheric Administration, 58 FR29186, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC), 1977, "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes," NUREG-0170, Office of Standards Development, U.S. Nuclear Regulatory Commission.

U.S. Nuclear Regulatory Commission (NRC), 1986, "Assessment of the Public Health Impact From the Accidental Release of UF_6 at the Sequoyah Fuels Corporation Facility at Gore, Oklahoma," NUREG-1189, Volume 1, U.S. Nuclear Regulatory Commission.

Virginia Port Authority, (VPA), 1992, "1991 Foreign Trade Annual Report, Ports of Virginia," Virginia Port Authority, Norfolk, Virginia.

Weiner, R.F. and Neuhauser, K.S., 1992, "Conservatism of RADTRAN Line-Source Model for Ports on the Commonwealth, 1988," Old Dominion University, Norfolk, Virginia.

Wilmot, E.L., "Transportation Accident Scenarios for Commercial Spent Fuel," SAND80-2124, Sandia National Laboratories, Albuquerque, NM.

SECTION 10.0

GLOSSARY

10.0 GLOSSARY

activity: The mean number of decays per unit time of a radioactive nuclide.

assay: The concentration by weight percent of a particular material.

autoclave: A strong, pressurized, steam heated vessel.

background radiation: The amount of radiation to which a member of the population is exposed from natural sources, such as terrestrial radiation due to naturally occurring radionuclides in the soil, cosmic radiation originating in outer space, and naturally occurring radionuclides deposited in the human body. This amounts to about 300 mrem per year in the U.S.

cascade: A connected arrangement of equipment for the separation of isotopes. A single device or process usually can produce only a small amount of isotopic separation, but if a number of these are connected together the effect can be accumulated and a significant amount of separation achieved. An example is a cascade used in the gaseous diffusion process.

commercial natural UF₆: Unirradiated uranium (containing 0.711 +/- 0.0004g, U-235 per 100g U).

Commonwealth of Independent States: Republics that were states in the former Soviet Union.

conveyance: Any vehicle, aircraft, vessel, freight container, or hold, compartment, or defined deck area of an inland waterway craft or seagoing vessel.

curie: A unit of activity equal to 3.7×10^{10} disintegrations/s.

depleted uranium: Uranium whose content of the isotope uranium-235 is less than 0.711 percent, which is the uranium-235 content of natural uranium.

diversion: The unauthorized removal of nuclear material from its approved use or location.

draw downs: Reducing the inventory of natural uranium inventories by feeding the uranium inventory into the nuclear fuel cycle process.

enriched uranium: Uranium whose content of the isotope uranium-235 is greater than 0.711 percent, which is the uranium-235 content of natural uranium.

feed stock: Natural uranium required for the enrichment process.

fissile class II: A package that may be transported together with other packages in any arrangement but, for criticality control, in numbers not exceeding an aggregate transport index of 50. These shipments require no other nuclear criticality safety control during transportation. Individual packages may have a transportation index not less than 0.1 and not more than 10.

fissile classification: The categorization of fissile material packages into one of the three fissile classes, based on the controls needed to provide nuclear criticality safety during transportation.

fissile material: Any material consisting of or containing one or more fissile radionuclides. Fissile radionuclides are plutonium-238, plutonium-239, plutonium-241, uranium-233, and uranium-235. Neither natural nor depleted uranium are fissile material. Fissile materials are classified according to the controls needed to provide nuclear criticality safety during transportation.

fissionable: A material or element that is capable of undergoing a nuclear reaction in which an atomic nucleus splits into fragments, usually of comparable mass, with the evolution of approximately 100 million to several hundred million electron volts of energy.

freight on board: A method of delivery of commercial goods whereby payment for the freight is made prior to shipment. As a result, the buyer is responsible for shipment costs.

gaseous diffusion process: A method of isotopic separation based on the fact that gas atoms or molecules with different masses will diffuse through a porous barrier (or membrane) at different rates.

half-life: Time required for a radioactive substance to lose 50 percent of its activity by decay.

highly enriched uranium (HEU): Uranium whose content of the isotope uranium-235 is greater than 20 percent.

inventory: book inventory - The quantity of nuclear material present at a given time as reflected by accounting records.

physical inventory - The quantity of nuclear material that is determined to be on hand by physically ascertaining its presence using techniques that include sampling, weighing, and analysis.

ionizing radiation: Radiation that can displace electrons from atoms or molecules, thereby producing ions.

low enriched uranium (LEU): Uranium whose content of the isotope uranium-235 is between 0.711 percent to less than 20 percent.

non-fissionable: A material or element that is not capable of undergoing a nuclear reaction in which an atomic nucleus splits into fragments.

overfeed: In the gaseous diffusion process, the process by which additional uranium is fed into the enriching system (cascade) in order to reduce the amount of separative work units required and reduce the amount of electricity consumed.

person-rem: Unit of population exposure obtained by summing individual dose-equivalent values for all people in the exposed population. Thus, the number of person-rem contributed by 1

person exposed to 1 rem is equal to that contributed by 100,000 people each exposed to 10 μ rem.

rad: The basic unit of absorbed dose of ionizing radiation. A dose of 1 rad means the absorption of 100 ergs of radiation energy per gram of absorbing material.

radioactive material (RAM): Any material having a specific activity greater than 0.002 μ Ci/g. A collective term that includes all radioisotopes, by-product materials, radium, radium compounds, and irradiated materials.

radioactivity: The property of some nuclides of spontaneously emitting particles or gamma radiation, emitting x radiation after orbital electron capture, or undergoing spontaneous fission.

radioisotopes: A radioactive atomic species of an element with the same atomic number and usually identical chemical properties.

rem: Unit of dose equivalent. The dose equivalent in "rem" is numerically equal to the absorbed doses in "rad" multiplied by the "quality factor," the distribution factor, and any other necessary modifying factor.

sampling: Testing to confirm assay and purity of a material coming to the GDP. This involves heating a UF_6 cylinder to convert the solid to a liquid and withdrawing a small amount for testing.

separative work unit (SWU): A SWU is a measure of the separation achieved in a uranium enrichment plant after separating uranium of a given U-235 content into two components, one having a higher percentage of U-235 and one having a lower percentage of U-235.

sievert (Sv): The International System of Units term for the unit of effective dose and equivalent dose; 1 Sv equals 100 rem.

sublimation (sublime): Process through which a solid material turns into a gaseous material or a gaseous material turns into a solid. This activity causes the liquid state to be bypassed.

tails assay: the concentration by weight percent of U-235 remaining in the depleted uranium stream produced during the enrichment process.

transportation index: The dimensionless number (rounded up to the first decimal place) placed on the label of a package containing radioactive materials to designate the degree of control to be exercised by the carrier during transportation. The transport index is determined as follows:

- The number expressing the maximum radiation level in mrem/hr at 1 m (3.3 ft) from the external surface of the package; or
- For Fissile Class II packages or packages in a Fissile Class III shipment, the number expressing the maximum radiation level at 1 m (3.3 ft) from the external surface of the package, or the number obtained by dividing 50 by the allowable number of packages that may be transported together, whichever is larger.

type A packaging: Packaging designed to retain the integrity of containment and shielding required under normal conditions of transport.

type B packaging: Packaging designed to retain the integrity of containment and shielding required when subjected to the normal conditions of transport and hypothetical accident test conditions.

uranium hexafluoride (UF_6): A volatile compound of uranium and fluorine. UF_6 gas is the process fluid in the gaseous diffusion process.

uranium ore: Rock containing uranium mineralization (typically 1 to 4 pounds of U_3O_8 per ton or 0.05 to 0.20 percent U_3O_8) that can be mined economically.

uranium oxide: Uranium concentrate or yellowcake. Abbreviated as U_3O_8 .

yellowcake: Concentrate of uranium oxide when in pure form.

APPENDIX A

TRUCK AND RAIL TRANSPORTATION RISK METHODOLOGY

APPENDIX A

TRUCK AND RAIL TRANSPORTATION RISK METHODOLOGY

Transportation risk analysis was performed for this EA through the use of the computer code RADTRAN 4 [SNL, 1992]. RADTRAN 4 contains idealized mathematical models for transportation environments. These models have been formulated to yield conservative estimates (i.e., those that tend to overstate the impact) of integrated population dose in a way that can be supported by available data. For example, RADTRAN 4 estimates that, in the event of an accident, people would not be evacuated for 24 hours. In actuality, people would most likely be evacuated sooner, thereby reducing the time of exposure. The models in RADTRAN 4 do not include features of the transportation environment that either do not affect the calculated risk values or reduce conservatism.

The RADTRAN 4 computer code combines user-determined meteorological, demographic, transportation, packaging, and material factors with health physics data to calculate the expected radiological consequence of incident-free and accidental risk of transportation of radioactive material. User-assigned parameters are defined by individual route segment links, for example, ocean passage or highway links between intersections of the various routes taken by the transportation conveyance. Environmental parameters that are quantified using values specific to each transportation link include transport distance, accident rates, and population density. All other environmental parameters, e.g., traffic densities, are left at recommended RADTRAN 4 values to yield conservative results. The reference [SNL, 1992], contains details of these default values.

The overland transportation of LEU was modeled by identifying the most direct route from the gate of each marine terminal yard to the nearest interstate highway using detailed city maps. The most direct route generally would minimize the risk. From the city road connection to the interstate system, a representative interstate route to the gate of the Portsmouth GDP at Piketon, Ohio, was developed with the HIGHWAY [ORNL, 1992] routing model, as discussed in the next paragraph.

Input parameters that describe the route and population distribution for the overland transportation segment from the proposed port of entry to Piketon, Ohio, are contained in the HIGHWAY computer routing program. The HIGHWAY program provides a flexible tool for predicting and describing highway routes for transporting radioactive materials in the United States. The HIGHWAY data base is essentially a computerized road atlas that currently describes over 240,000 miles of highways. Complete descriptions of all interstate systems and most U.S. highways (except those that parallel nearby interstate highways) are included in the data base. Many of the principal state highways and a number of local and county highways are also identified. The data base also includes locations of nuclear facilities and major airports, including the Portsmouth and Paducah GDPs. Routes are calculated by minimizing a combination of distance and driving time for a highway route between two points. Several routing constraints can be imposed during the calculations.

One of the special features of the HIGHWAY model is its ability to identify routes that maximize use of interstate system highways. This feature allows the user to establish baseline routes for shipments of radioactive materials that conform to DOT routing regulations, which require that interstate system highways be used to the maximum extent possible. This explains why the same major highways would be repeatedly used for shipments of radioactive materials, rather than alternate routes over non-interstate highways. Within the context of risk assessment, these routes should be considered as representative of typical routes that might be used for normal transportation between two points. Specific routes cannot be predicted because factors such as weather, construction, accidents involving other vehicles, and local and state ordinances can change the route that might be used for transportation. Other features of the model include the ability to predict routes that bypass a specific city, town, or highway segment.

Two unique features have been incorporated in HIGHWAY, Version 3.1. The first is the ability to automatically identify alternative routes. Frequently, there are a number of routes between the source and destination that vary slightly in distance and estimated driving time. Most routing models will produce only a single route. With the alternative routing feature, the HIGHWAY program offers a selection of different but nearly equal routes. The second special feature is the capability to calculate route-specific population density statistics. The population density distribution is calculated for each highway segment in the route and is reported on a state-by-state basis. The population information used for this calculation is based on data from the U.S. Bureau of Census, which is routinely updated.

Rail

The overland rail transportation of LEU was modeled by identifying the most direct rail route from each marine terminal yard to the Portsmouth GDP. The most direct route generally would minimize the risk. From the port rail spurs, a representative rail route to the gate of the Portsmouth GDP at Piketon, Ohio, was developed with the INTERLINE [ORNL, 1992] rail routing code, as discussed in the next paragraph.

Input parameters that describe the route and population distribution for the overland transportation segment from a selected representative proposed or alternative port of entry to Piketon, Ohio, are contained in the INTERLINE computer routing program. The INTERLINE program provides a flexible tool for predicting and describing rail routes for transporting radioactive materials in the United States. The data base is essentially a computerized atlas that currently describes the U.S. rail network. Complete descriptions are included in the data base. The data base also includes locations of nuclear facilities with rail service, including the Portsmouth and Paducah GDPs. Routes are calculated by maximizing distance traveled by the initial carrier company and by otherwise minimizing a combination of distance and travel time. Maximizing in this way reduces the potential number of classifications.

Within the context of risk assessment, these routes should be considered as representative of typical routes that might be used for normal transportation between two points. Specific routes cannot be predicted because factors such as weather, construction, accidents involving other vehicles and unforeseen rail abandonments, can change the route that might be used for transportation.

Routes are calculated by maximizing distance traveled on railways owned by the original carrier rail company because this approximates actual rail company practice and because time spent in classification yards is minimized. Rail stop times are considerably greater than for highway transportation because of inspections and classifications. Classifications occur at centrally located classification yards, which act as "hubs" into which come trains from a port, for example, consisting of cars bound for diverse destinations. The railcars are inspected, disassembled and reassembled into new trains that leave the classification yard on separate rail lines. A railcar that must travel a long distance and/or travel on a number of different rail companies' lines will undergo several classifications. Because the United States rail network is not extensive, total distance traveled is less flexible than for highway, but by minimizing the number of rail-company interchanges to the extent possible, INTERLINE minimizes total time in transit. Average stop time for a rail journey in the United States is 60 hours.

The INTERLINE calculates route-specific population density statistics. The population density distribution is calculated for each rail segment in the route and is reported on a state-by-state basis. The population information used for this calculation is based on 1990 data from the U.S. Bureau of Census, which is routinely updated.

APPENDIX B

MARITIME ACCIDENT ENVIRONMENTS

APPENDIX B

MARITIME ACCIDENT ENVIRONMENTS

B.1 Introduction

Hypothetical maritime accidents can be described in a sequence as the vessel travels from the open ocean to dockside or vice versa. First, accidents of all severities on the open seas occur with a frequency of from 2.9×10^{-4} to 5.8×10^{-4} accidents per trip, with the lowest value being for the Atlantic Ocean and the highest value for the Gulf of Mexico. As a vessel nears port, it enters more congested waters (e.g., port approach channels and the open waters of a bay or harbor). Velocities tend to decrease, but accident frequencies increase because of the increased ship traffic and relative proximity of one vessel to another. Port accident statistics do not distinguish between ships in transit within port waters and stationary vessels (e.g. vessels at anchor or dockside). Accidents occur in Atlantic ports at an average rate of about 1.6×10^{-4} per port transit, but higher rates are recorded for some other U.S. ports (e.g., 1.5×10^{-3} accidents per port transit in the Houston ship channel) [Warwick and Anderson, 1976]. A U.S. average rate of 2.4×10^{-4} accidents per port transit was used for all ports in this analysis.

Historically, about 54 percent of all accidents in port and on the open seas are collisions [Warwick and Anderson, 1976]. For port accidents, only about 2.5 percent involve fires [Operations Research, 1979]. The remaining accidents (about 43 percent) are groundings and other non-collision accidents [Warwick and Anderson, 1976]. Since vessels generally move on the open seas with higher velocities than in ports, collision accidents on the open seas tend to be more severe. Although speed limits may be posted in highly congested or narrow areas of channels and harbors, the velocity of a vessel in port is usually left to the discretion of the vessel pilot and ultimately is the responsibility of the ship's master.

Almost half (45 percent) of collisions that occur in a port involve one vessel at anchor [Operations Research, 1979]. Thus, a vessel carrying radioactive material has about an equal probability of being either the struck vessel or the striking vessel.

A collision and/or fire involving a vessel carrying radioactive material that occurs at or near a dock area would present the greatest potential for public exposure because there is no intervening expanse of open water. Thus, for the purpose of conservatism in this analysis, port accidents are modeled as occurring at dockside, even though most port accidents in fact occur at other locations [Warwick and Anderson, 1976].

B.2 Maritime Accident Environments

Historical maritime accident statistics have been examined to estimate the probabilities of subjecting a cargo hold in which radioactive material is stowed to potentially threatening environments. In previous environmental assessments, the term "crush" was used to designate the composite of mechanical forces that might occur in a real maritime accident (DOE/EA-0321, DOE/EA-0363). However, this term also has a specific meaning in package certification testing procedures, and to avoid confusion the term "mechanical forces" will be used in this analysis to represent the composite. Technically, this composite of mechanical forces may include impact, puncture, and crush forces. However, puncture forces generally do not present a threat to the packaging used to transport the UF_6 and the mechanical forces of concern are mainly impact and possibly, crush forces. The frequencies of occurrence of these forces and other accident environments are presented in Table B-1.

Table B-1. Frequency of Accident Environment per Hold Port Transit [Warwick and Anderson, 1976]

Mechanical	Immersion	Fire
2.05×10^{-5}	4.00×10^{-4}	5.28×10^{-5}

B.3 Packaging Response to Immersion

For accidents in a port, the immersion environment is rather benign since port waters average less than 200 meters in depth, and a Type 30B cylinder in an overpack can easily survive immersion at a depth of 200 meters. The Mont-Louis is the only ship to ever sink while carrying UF_6 cylinders. All of the cylinders were recovered from the sunken ship. Present-day salvage techniques allow for easy recovery of packages at depths of up to 200 meters from the sea bed [Kage et al., 1980].

B.4 Packaging Response to Mechanical Forces

Collisions are among the most potentially severe accidents that occur in the region of a port. Although some groundings could be severe enough to tear the ship's hull structure and perhaps even cause flooding of some cargo compartments, groundings present less of a threat of mechanical damage than collisions. Table B-2 is a profile of collision experience in nine major U.S. ports (New York, Baltimore, Hampton Roads, New Orleans, Houston, Galveston, Los Angeles/Long Beach, San Francisco, and Oakland) for cargo vessels with a displacement greater than 1000 gross tons [Warwick and Anderson, 1976].

The data in this table are derived from U.S. Coast Guard data for 1970 to 1974 [Warwick and Anderson, 1976]. During this period 296 collisions occurred out of a total of 140,000 port transits. Of these 296, only two involved severe damage, and only one of these involved fire. Thus, a severe collision was modeled in this analysis as having a probability of occurrence of about 1.4×10^{-5} .

**Table B-2. Summary of Port Collisions 1970-1974
Vessels over 1000 Gross Tons**

Meeting	Crossing	Overtaking	Anchored	Fog	Total
79	20	20	132	45	296
26.7%	6.8%	6.8%	44.6%	15.2%	100%

The data summarized in Table B-2 include a subset of 72 collisions that were classified as severe, based on monetary damage [Warwick and Anderson, 1976]. In only two of those cases was the damage greater than \$200,000 (1975 dollars), and one of these, the Sea Witch-Esso Brussels collision, was a collision in which a fire developed after impact. The total damages for this collision were estimated at the time to be approximately \$23 million. This accident is discussed in detail in Section B-5.

Another somewhat more recent survey of 777 maritime accidents and incidents in Atlantic and Gulf Ports is summarized in Table B-3 [Abkowitz and Galarraga, 1985].

**Table B-3. Accidents in Atlantic and Gulf Coast Waters and Ports
[Abkowitz and Galarraga, 1985]**

Accident Type	Atlantic Waters	Gulf Coast Waters	Atlantic Ports	Gulf Coast Ports	Total
Collision	7	25	71	320	423
Fire/ Explosion	0	11	9	8	18
Grounding	2	6	54	139	201
Other	20	23	34	58	135
Total	29	65	168	525	777

Collisions accounted for 50.4 percent of the total, which confirms the earlier finding [Warwick and Anderson, 1976] that collisions represent the most common accident threat in a port. As noted previously, it is conservative to model all accidents as occurring at the dock (i.e., adjacent to shore without intervening expanse of water).

B.4.1 Container Drops During Off-loading

Another category of accident that is not related to ship collisions is container drops during handling. The possibility of UF₆ container damage occurring during handling at the dock was considered in this analysis. The ports in the proposed action handle large amounts of containerized cargo (e.g., Hampton Roads, VA handles at least 750,000 containers annually). A move is defined as an operation in which a crane picks up a container, moves it, and disengages. Virginia International Terminals, Inc. (VIT) estimates that, at most, 1 or 2 containers are dropped per year [Hawkins, 1991]. This amounts to an historical probability of a container drop of about 2.7×10^{-6} (less than 3 in one million moves). The foremost cause of drops is container defects [Hawkins, 1991]. Since the main cause of drops is related to the container rather than to specific operations at Hampton Roads, the statistical probability can be assumed to be approximately the same at all ports considered in this analysis.

The berths at ports considered in this analysis consist of either concrete aprons constructed on friction pilings driven into the sediment or bedrock or on tamped earth contained within sheet pilings. Both are relatively yielding surfaces, and the water or the deck of a ship are even more yielding than a dock surface. Previous studies have shown that a package can be dropped onto yielding surfaces from much higher than 30 feet without sustaining damage. This is much greater than the force sustained during the regulatory drop test [Fisher, et al., 1987; Gonzales, et al., 1986].

In conclusion, the probability of a container drop is low, and no release would be expected to occur as the result of a container drop even if the drop were greater than 30 feet. Thus, container drops during unloading of the Russian LEU are not a credible means of damaging a cylinder, and this accident type is not considered further in this analysis.

B.5 Packaging Response to Fire

Packagings of the type used to carry the Russian LEU are designed to survive the thermal load specified in the licensing performance criteria (i.e., the thermal load from a fully engulfing fire at 1475°F for 30 minutes) with no release of contents. It is important to explain that a fire that only exceeds the regulatory fire temperature of 1475°F or that only exceeds the regulatory fire duration of 30 minutes does not mean that the packaging performance criteria necessarily have been exceeded. In order for the performance criteria to be exceeded, not only must the total thermal input to the packaging exceed that delivered during the regulatory fire, but it must be delivered to the packaging in a manner that does not permit the heat to be re-radiated by the packaging. That is the reason for the full engulfment requirement in the regulatory test—to prevent re-radiation of heat. A non-engulfing fire (e.g., a fire adjacent to a packaging) would have to be hotter and burn longer to deliver the same amount of heat to the packaging [Fisher, et al., 1987].

The data in Table B-1 indicate that fires are historically a small fraction of maritime accidents. Cargo ships are equipped with fire suppression equipment to handle most fires. Historical records regarding maritime accidents indicate that while some severe fires have occurred, they represent no more than 3 percent of all ship fires or less than seven in 10,000 maritime accidents (a frequency of 0.00069 or 6.9×10^{-4}) [Operations Research, 1979]. This 3 percent of severe ship fires often involve flammable liquids and may burn for many hours or days or until the ship sinks [Operations Research, 1979], but fires of this type occur almost exclusively on ships carrying petroleum products (e.g., oil tankers). A cargo ship carrying Russian LEU might become involved in such a fire if it were involved in a collision with a tanker whose contents subsequently ignited. As shown in the Sea Witch-Esso Brussels accident, which was a real accident involving a burning oil tanker and a containerized cargo ship that did not sink but ran aground, the accident demonstrated that even such a collision and fire does not present a threat to a cylinder of LEU stowed below deck [DOE/EA-0515].

When the consequences of a fire involving an oil tanker are considered, one should note that crude oil fires have a radiative heat flux of about 41 kilowatts per square meter. Refined hydrocarbon fuels such as JP4 aviation fuel and gasoline burn with a radiative heat flux of about 120 kilowatts per square meter. In other words, crude oil burns cooler than gasoline-type fuels. This means that a crude oil fire must burn longer than a gasoline-type fire to deliver the same amount of heat.

Since stowage regulations require that no other hazardous or flammable material be stowed in the same hold with radioactive materials, the largest potential on-board source of flammable material to sustain a major fire in a cargo ship carrying Russian LEU is the ship's fuel supply. This would be close to the reserve capacity of 40-50 MT of fuel when the ship enters a U.S. port at the end of an overseas voyage. Leaving aside the problem of devising a credible means by which this fuel supply might come to be released within a cargo hold, ignite without activation of the automatic on-board fire-suppression system, and engulf a SEAPAK, such a fire would be equivalent to an enclosed pool fire. It has been shown that "entrainment [of air] and mixing are the rate determining steps for combustion in pool fires" [Considine, 1984]. In an enclosed space such as a ship's cargo hold, the free flow of air is limited, and the rate of combustion would be less than for open pool fires of the same fuel. The production of large quantities of smoke, which is typical of "inefficient" combustion of this sort lowers the flame temperature of the burning fuel. It can also "shroud the flame reducing the amount of flame seen by the object at any one time" [Considine, 1984]. The atmospheric transmissivity of heat from a fire is also reduced by high relative humidity [Considine, 1984], which is characteristic of the marine environment. In short, the factors listed above would all act to reduce the effects of a cargo-hold fire regardless of the source of the fuel, but no attempt was made in this analysis to account for such reduction of accident severity. In

practice, mitigating measures such as flooding a hold with water could be used to prevent casks from experiencing excessive thermal loads, but again no credit was taken for these measures in this analysis.

DOT regulations governing the transport of radioactive materials would preclude the storage of more than eight cylinders of LEU (or two SEAPAKs) in one hold or defined deck area [49 C.F.R. § 176.704]. Therefore, it is reasonable to assume that in a single accident with the possible mechanisms discussed above by which a UF_6 cylinder might be exposed to fire no more than two SEAPAKs on a ship could experience a thermal load sufficiently great to result in a release of contents. However, for purposes of conservatism it was assumed that in the event of a severe collision and fire that there would be a total release of contents from half of the cylinders on board. For a cylinder to release some fraction of its contents as a result of thermal loads experienced during an accident, the overpack and the cylinder must have failed and the packaging must be subjected to a fire that greatly exceeds those encountered in the regulatory certification tests.

In the Sea Witch-Esso Brussels accident, severe fire conditions occurred only above-deck and only in highly localized areas (i.e., in areas smaller than that occupied by an ISO container), and not at all in below-deck areas. None of the areas where severe fire occurred were also subjected to severe impact. Nevertheless, this was probably the worst maritime accident in U.S. history involving a cargo ship. It illustrates the fact that a cargo ship occupies a large volume and that even where all necessary factors appear to be present in an accident, unless they all occur in the same relatively small volume and unless that small volume is where a UF_6 cylinder would be located (i.e., below deck in a cargo hold), there would be no consequences.

Finally, it can be concluded that the simultaneous occurrence within another area on the same ship during the same accident of either fire exceeding 1475°F for 4 hours or some other combination of fire and impact exceeding that required for cylinder and overpack destruction is highly improbable.

B.6 Probability of a Severe Accident

Probability of a Severe Accident from U.S. Coast Guard Data [Operations Research, 1979]

Approximately 73 percent of the marine accidents reported to the U.S. Coast Guard (USCG) are in inland waters. The remaining 27 percent occurred on the open seas. Only the collision accident frequencies in inland waters are used in this analysis, and it is further assumed that these collisions occur in the region of a port. Since the data are for a 2-year time span, the basic accident rate is based on the number of port transits or port calls that occurred in the 2-year interval. There were approximately 39,000 port calls in each year; thus, the total number of port calls was 78,000. There were 196 collisions during the 2-year period. Therefore, the basic collision accident probability (C_{cr}) is

$$C_{cr} = 196/78,000 = 2.5 \times 10^{-3} \text{ collisions per port call.}$$

In the reference [Abkowitz and Galarraga, 1985] it is noted that only 5 in 72 port collisions, about 7 percent, were severe. In addition, if a radioactive material transport vessel were involved in a collision, the most damaging situation for the cargo would be when the radioactive material transport vessel was the struck vessel. Considering the dimensions of a typical cargo vessel (a displacement of about 13,000 gross tons, fitted with seven cargo holds, but with no bulkhead between holds 6 and 7, therefore, essentially six holds) only one cargo hold would be struck, and it is assumed for purposes of conservatism that one hold is loaded with 50 percent of the cylinders of UF_6 . Therefore, assuming that there is a uniform probability of striking each hold, then the probability would be one in six or 0.167 that the radioactive material hold was struck. The probability of a severe collision is the basic collision rate times

the number of severe collisions times the probability of striking one hold. Thus, a severe collision probability is C_{sy} , where:

$$C_{sy} = (2.5 \times 10^{-3})(0.07)(0.167) = 2.9 \times 10^{-5} \text{ severe collisions per port call.}$$

Reference [Warwick and Anderson, 1976] examined 5 years of collision records for seven selected ports. There were 296 collisions during the 5-year period involving 602 vessels. Of these collisions, 72 involved two vessels greater than 1,000 gross tons each. Each of these 72 cases was examined for the amount of monetary damage to each vessel, because it was assumed that for there to have been any significant damage, at least one vessel would have had to sustain significant monetary loss. Of the 72 cases there were only 16 in which the reported monetary loss was greater than \$100,000 for each vessel. There were only five cases in which the monetary loss was greater than \$200,000, and only one of the 72 cases involved a fire that contributed to the monetary loss. Thus, the possibility of a fire following a severe collision would be 1 in 72 or about 1.4 percent. If a fire does occur on a ship, the probability that it is a severe fire is approximately 2.8 percent. Therefore, the basic accident rate given above can be modified to account for the conditional occurrence of a fire; that is,

$$\begin{aligned} \text{Probability of a severe fire following a collision} &= (2.9 \times 10^{-5})(0.014)(0.028) \\ &= 1.1 \times 10^{-8} \text{ per port call.} \end{aligned}$$

Probability of a Severe Collision Followed by a Severe Fire Based on the Penetration of the Cargo Hold During the Collision

Reference [Operations Research, 1979] performed a detailed study of the probability that a cargo hold would be penetrated during a collision, thereby presenting the environments of crush, immersion, or fire to the cargo hold. For a scenario in which one cargo hold contains spent fuel or other radioactive material, the probability of crush or fire as an insult to a radioactive material package is on the order of 2.0×10^{-5} per port call. This value can be modified, as above, to estimate the occurrence of a severe collision followed by a severe fire. That is, since 1.4 percent of the collisions are severe and followed by fire, and about 2.8 percent of the fires that occur are severe, it can be concluded that the probability of a severe collision followed by a severe fire = (2.0×10^{-5}) times (0.014) times $(0.028) = 7.8 \times 10^{-9}$ per port call.

By two relatively independent methods, the probability of occurrence of a severe collision followed by a severe fire in a port has been estimated. These estimates range from 7.8×10^{-9} to 1.1×10^{-8} per port call.

References

Abkowitz, M., and J. Galarraga, 1985, "Tanker Accident Rates and Expected Consequences in U.S. Ports and High Seas Regions," Conference on Recent Advances in Hazardous Materials Transportation Research: An International Exchange, Transportation Research Board, National Research Council.

Considine, M., 1984, "Thermal Radiation Hazard Ranges from Large Fuel Fires," SRD-R-297, United Kingdom Atomic Energy Authority, Culcheth, Warrington, England.

Fisher, E.L., et al., 1987, "Shipping Container Response to Severe Highway and Railway Accident Conditions," NUREG/CR-4829, Nuclear Regulatory Commission, Washington, D.C.

Gonzales, A., Pierce, J., and Stenberg, D., 1986, "Target Hardness Comparison to IAEA Unyielding Target," IAE-SM-114, SAND86-0052, Albuquerque, NM.

Hawkins, D., 1991, Letter of Information, Letter from Hawkins, Risk Manager, Virginia International Terminals.

Kage, K., Kuwashima, K., and Kijishima, H., 1980, "On the Domestic Transportation Hinoura Maru, the Ship for the Exclusive Use of Spent Nuclear Fuel," PAT Radioactive Material '80, Proceedings of the 5th International Symposium, Packaging and Transportation of Radioactive Materials, West Berlin, FRG.

Operations Research, Inc., 1979, "Hazardous Environments Experienced by Radioactive Material Packages Transported by Water," Contractor Report to Sandia National Laboratories, Silver Spring, MD.

U.S. Department of Energy (DOE), 1991, "Environmental Assessment of the Risks of the Taiwan Research Reactor Spent Fuel Project," DOE/EA-0515, Washington, D.C.

Warwick, J.E., and A.L. Anderson, 1976, "The Nature of Ship Collisions within Ports," Todd Shipyard Corp., Galveston, TX, prepared for the U.S. Maritime Administration.

APPENDIX C

DETERMINATION OF ANNUAL PORT WORKER EXPOSURE FROM COMMERCIAL RADIOACTIVE SHIPMENTS

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To estimate the annual exposure rate of port workers resulting from handling of commercial radioactive shipments, the following must be determined:

Number of radioactive packages handled per year
Length of exposure time per package
Dose rate per package

Records of shipments through the Ports of New York and New Jersey, Hampton Roads, Philadelphia, Houston, Charleston, Savannah, and Baltimore for recent years were used to estimate the annual throughput of packages with radioactive contents. Radioactive materials were identified by the product code listed for each shipment. To obtain an estimate of annual radioactive shipments (both imports and exports), a list of all shipments from July 1, 1992 through June 30, 1993 was compiled from the *Piers Imports and Exports, Journal of Commerce*. The radioactive shipments were grouped into five categories and exposure rates at one meter from the outer surface of the package were assigned for each group as follows:

enriched uranium hexafluoride	0.5 mrem / hour
normal uranium hexafluoride	0.2 mrem / hour
depleted uranium	0.2 mrem / hour
uranium oxide	0.2 mrem / hour
other radioactive materials	0.2 mrem / hour

Each shipment record in *Piers* listed the weight and number of packages included in the shipment. Package descriptions were not uniform and included units, containers, cases, boxes, drums, barrels, packages, cartons, units, cylinders, tanks, skids, or a mix of packages. The assumption was made that radioactive shipments would be stacked on skids and the total number of skids per shipment, rather than the number of packages per shipment, was needed to estimate the dose received by workers. The weight and number of individual shipments was examined for each shipment to estimate the number of skids. In most cases, boxes, cartons, barrels, and drums were assumed to be handled four to a skid. When a large number of light packages was included in one shipment, these were assumed to be handled as either 8 or 32 packages per skid.

The annual dose to port workers resulting from handling commercial radioactive shipments was estimated based on the number of shipments passing through the port and an estimated handling time of ten minutes per skid or cylinder. Each port uses three shifts per day and therefore workers were assumed to be exposed to one-third of the packages passing through the port. This is a conservative assumption given that there are typically many berths and terminals within one port, thus making it unlikely one individual would be present for even one-third of the shipments of radioactive materials.

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