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Final Rule for Radon - 222 Emissions from Licensed Uranium Mill Tailings

Economic Analysis

40 CFR Part 61
National Emission Standards
for Hazardous Air Pollutants

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FINAL RULE FOR RADON-222
EMISSIONS FROM LICENSED URANIUM MILL TAILINGS

ECONOMIC ANALYSIS

August 1986

Prepared For

Office of Radiation Programs
U.S. Environmental Protection Agency
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CHAPTER 1: INTRODUCTION

EPA issued environmental standards for nuclear power operations (40 CFR Part 190) in 1977. These standards limit the total radiation dose caused by radionuclide emissions from facilities that comprise the uranium fuel cycle, including uranium mills and tailings. However, the dose due to radon-222 was exempted from the standard. At the time 40 CFR 190 was promulgated, there existed considerable uncertainty about the public health impact of existing levels of radon-222 as well as uncertainty about the best method for management of new man-made sources of radon-222. It was decided to consider radon-222 separately under a subsequent standard.

When EPA promulgated emission standards under the Clean Air Act for radionuclides emitted from licensed commercial processing facilities (40 CFR 192) in October of 1983, those NRC facilities previously regulated under 40 CFR 190, such as uranium mills, were exempted because they were subject to a rule that provided protection substantially equivalent to that of the Clean Air Act rule. Consequently, radon-222 emissions from operating uranium mills were not included in either of the above rules.

EPA did consider radon-222 emissions from licensed uranium mills when standards (10 CFR 192) were issued under the Uranium Mill Tailings Radiation Control Act (UMTRCA) in 1983 for the management of tailings at locations that are licensed by the NRC or Agreement States under Title II of that law. But the final rule did not limit radon-222 emissions until after the closure of the facility and termination of the mill operating license except to apply the "as low as reasonably achievable" (ALARA) principle in establishing management procedures and regulations during operation. EPA did state, at the time UMTRCA standards were promulgated, that an Advanced Notice of Proposed Rulemaking would be issued to consider control of radon-222 from tailings piles during the operational period of an uranium mill.

On October 31, 1984, EPA announced in the Federal Register an Advance Notice of Proposed Rulemaking to inform interested parties that the Agency is considering standards for radon-222 emissions for licensed uranium ore processing facilities (uranium mills) under the Clean Air Act. Subsequently, EPA entered into an agreement with the Sierra Club to promulgate these standards by May 1, 1986. By agreement of these parties this date was changed to August 15, 1986. This was formalized by a court stipulation from the United States District Court for the Northern District of California.

This document presents the findings of an economic analysis of alternative proposed work practices for controlling radon-222 emissions during the operation of licensed uranium mills. The report contains separate chapters which discuss the:

- current status of the domestic uranium milling industry;
- current radon-222 emissions and risk estimates;
- baseline forecasts of production, emissions, and health effects in the absence of the proposed rules;
- descriptions of proposed alternative work practices for controlling radon-222 emissions from tailings impoundments;
- estimates of the benefits and costs of these alternative work practices;
- the probable economic impacts of the proposed rules; and
- consideration of the financial impacts of the proposed rule on the owners of existing and future mills, and the consumers of nuclear-generated electricity.

A draft of this document and of the Background Information Document (BID) were distributed to the public in early 1986. Public hearings were conducted in March 1986 and several comments on the assumptions utilized in this report were presented. The principal areas of concern referred to the interim cover option and the length of time it was assumed that a facility would remain idle prior to final stabilization. In addition, comments stressed the poor economic conditions in the uranium mining and milling industries.

This document has been revised to address these concerns raised by the public. First, the interim cover option has been revised to account for technical difficulties in covering the evaporation ponds and sides of tailings piles. Second, the report now includes two alternate assumptions about the length of time a pile may remain idle prior to final stabilization. In addition to the 40-year assumption contained in the primary analysis, a complete set of costs and benefits for each regulatory alternative has been developed for a much shorter idle period of 20 years.

Finally, the economic condition of the uranium industry and market is reaching an all-time low. All facility owners are continuously evaluating their investments and considering future costs and market uncertainties and some have chosen to permanently close their plants in 1986. For the purpose of this analysis, industry data is current through February 1, 1986.

CHAPTER 2:

INDUSTRY PROFILE

The U.S. uranium milling industry is an integral part of a domestic uranium production industry that includes companies engaged in uranium exploration, mining, milling, and downstream activities leading to the production of fuel for nuclear power plants. The product of uranium milling is uranium concentrate, also referred to as uranium oxide, yellowcake, or U_3O_8. Uranium concentrate may be produced either from mined and milled ore or through alternative sources such as solution mining, heap leaching, mine water, mill tailings, low-grade stockpiles, and as a byproduct of other activities. Conventional production from mined and milled ore is the focus of this report.[1] In 1984, conventional production amounted to 64.4 percent of total U_3O_8 production of 7,450 tons (DOE 85a).

The following pages describe the supply and demand characteristics of the conventional uranium milling industry. Section 2.1 provides an overview of current and historical sources of U_3O_8 (domestic production, imports, and inventories) and analyzes the cost of production. Section 2.2 characterizes the use of uranium by the nuclear power industry, describes factors influencing demand, and reviews uranium pricing mechanisms. Section 2.3 concludes the chapter with a review of industry structure and performance, including industry and individual company statistics on capacity, production, employment, mill location, and financial performance.

2.1 SUPPLY

2.1.1 Sources of Supply

The uranium used to fuel nuclear reactors is supplied by domestic and foreign producers; the removal of uranium from utility inventories; and secondary market transactions such as producer-to-producer sales, utility-to-utility sales and loans, and utility-to-producer sales. The role of each is described in the following sections.

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[1]Production from alternative sources does not produce the mill tailings that are the object of the proposed regulation. Two of the alternative sources, mine water and heap leaching, frequently go through the secondary milling circuit but never the primary circuit. They therefore contribute to the liquid portion of mill tailings but not the solid portion. The other alternative sources are not milled.

Domestic Production

Exhibit 2-1 shows trends in domestic uranium production from 1947 to 1984, by state. Total production was relatively constant at 10,500 to 12,500 tons per year until 1977, when it began an increase that peaked in 1980 at 21,852 tons. Production has declined in each year since, reaching only 7,441 tons in 1984 (DOE 85b).

Coinciding with the overall decline in the domestic production industry is a decline in the share of production represented by conventional mills, as production from other sources has remained fairly steady. Conventional milling has historically accounted for over 90 percent of U.S. production. In 1983, the conventional share of production fell to 70.6 percent, and in 1984 dropped again, to 64.7 percent (Exhibit 2-2). The result has been severe overcapacity and mill closings (DOE 85a). Milling capacity, which almost doubled between 1975 and 1980 when the price of uranium was high and optimistic demand forecasts stimulated investment in milling facilities, once enjoyed a utilization rate of 94 percent (JFA 85a). In March 1985, capacity utilization was about 71 percent at operating mills. The number of operating mills has declined dramatically also, from 20 in 1981 to only two in June 1985 (DOE 85a). Industry sources indicate that the two remaining mills are now operating at less than 50 percent of capacity (DOE 85a). Uranium mill capacities and utilization levels are listed in Exhibit 2-3.

Imports

A second source of uranium is the import market. From 1964 to 1976, foreign uranium was effectively banned from U.S. markets by a law prohibiting the enrichment of imports for domestic use. This restriction was lifted gradually after 1977, and was eliminated completely by 1984. As a result, imports grew from zero prior to 1975, to 37.4 percent of U.S. requirements in 1984 (DOE 85a). The primary sources of U.S. uranium imports are Canada, South Africa, and Australia. In 1983, 66 percent of U.S. uranium imports were from Canada, 26 percent were from South Africa, and the remaining eight percent were from various other nations (DOE 84a). Exhibit 2-4 shows the history of U.S. imports from 1967 through 1984.[1]

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[1]The unusually high 1982 figure of 8,500 tons included a large exchange transaction which should be excluded to obtain a more realistic picture of imports. Eliminating this transaction, 1982 imports were only slightly higher than in 1983.

EXHIBIT 2-1:

TOTAL URANIUM CONCENTRATE PRODUCTION, 1947-1984

(Short Tons U_3O_8)

Year(s)	Colorado	New Mexico	Texas	Utah	Wyoming	Others[a]	Total
1947-1965	29,652	54,301	(b)	28,924	18,449	8,380	139,706
1966	1,423	5,076	(b)	(c)	2,248	1,842	10,589
1967	1,340	5,933	(b)	(c)	2,667	1,313	11,253
1968	1,614	6,192	(b)	(c)	2,873	1,689	12,368
1969	1,678	5,943	(b)	(c)	3,063	925	11,609
1970	(c)	5,771	(b)	(c)	3,654	3,480	12,905
1971	(c)	5,305	(b)	(c)	3,487	3,481	12,273
1972	(c)	5,464	(b)	(c)	4,216	3,220	12,900
1973	(c)	4,634	(b)	(c)	5,159	3,442	13,235
1974	(c)	4,951	(b)	(c)	3,767	2,810	11,528
1975	(c)	5,191	(c)	(c)	3,447	2,962	11,600
1976	(c)	6,059	(c)	(c)	4,046	2,642	12,747
1977	(c)	6,779	(c)	(c)	4,990	3,170	14,939
1978	(c)	8,539	(c)	(c)	5,329	4,618	18,486
1979	(c)	7,423	2,651	(c)	5,452	3,210	18,736
1980	(c)	7,751	3,408	(c)	6,036	4,657	21,852
1981	(c)	6,206	3,141	(c)	4,355	5,535	19,237
1982	(c)	3,906	2,131	(c)	2,521	4,876	13,434
1983	(c)	2,830	1,600	(c)	2,630	3,519	10,579
1984	(c)	1,458	1,310	(c)	1,560	3,113	7,441

[a]Includes, for various years, Arizona, Colorado, Florida, Louisiana, South Dakota, Texas, Utah, and Washington.

[b]Data were not collected.

[c]Included in the "Others" category.

Source: DOE 85b

EXHIBIT 2-2:
PRODUCTION OF URANIUM CONCENTRATE
BY CONVENTIONAL MILLS
AND OTHER SOURCES
1974-1984
(Short Tons U_3O_8)

Year	Conventional Production	Other Production[a]	Total Production	Conventional Production As Percent Of Total
1978	17,172	1,315	18,486	92.9
1979	16,877	1,860	18,736	90.0
1980	18,903	2,950	21,852	86.5
1981	15,998	3,239	19,237	83.2
1982	10,447	2,988	13,434	77.8
1983	7,760	2,820	10,579	73.3
1984	4,813	2,628	7,441	64.7

[a]Saleable U_3O_8 obtained from in situ leaching and as a byproduct of other processing.

Source: DOE 85b

EXHIBIT 2-3:

URANIUM MILL CAPACITY

(Tons of Ore Per Day)

	Total Capacity	Operating Capacity	Operating Capacity Utilization Rate	Total Capacity Utilization Rate
1981	54,050	49,800	83	77
1982	55,050	33,650	74	45
1983	51,650	29,250	58	33
1984	48,450	19,250	64	25
March 1985	49,450	11,950	71	18

Source: DOE 85a

EXHIBIT 2-4:
IMPORTS OF URANIUM CONCENTRATE FOR COMMERCIAL USES 1974-1984
(Short Tons U_3O_8)

Year of Delivery	Imports
1974	0
1975	700
1976	1,800
1977	2,800
1978	2,600
1979	1,500
1980	1,800
1981	3,300
1982	8,550
1983	4,100
1984	6,250

Source: DOE 85b

Forecasts of import penetration call for the import share to grow through the 1990's. The Department of Energy projects that without government intervention, between 1990 and 2000 imports will range between 54 and 69 percent of domestic utility requirements, depending on demand levels. Government action is a real possibility however. Public Law 97-415 calls for a special study of the uranium industry at any time that executed contracts or options for source material will result in greater than 37.5 percent of actual or projected domestic uranium requirements for any two-consecutive-year period. According to DOE estimates, current import commitments make up no more than 32 percent of U.S. utility requirements in any year between 1985 and 2000. However, if utilities continue to turn to foreign sources at the rates seen in recent years, executed contracts for imports will rise above 37.5 percent of requirements and possibly trigger Federal intervention (DOE 85a).

Inventories

Utilities hold uranium inventories in order to meet changes in the scheduling of various stages of the fuel cycle, such as minor delays in deliveries of uranium feed. Uranium inventories also protect the utilities against disruption of nuclear fuel supplies. The average "forward coverage" currently desired by domestic utilities (in terms of forward reactor operating requirements) is 18 months for natural uranium (U_3O_8) and seven months for enriched uranium hexafluoride (UF_6) (DOE 85a).

Exhibit 2-5 lists inventories of commercially owned natural and enriched uranium held in the United States as of December 31, 1982, 1983, and 1984. DOE-owned inventories are not included. The uranium inventory owned by utilities alone at the end of 1984 represented almost five years of forward coverage. Including the 11,950 tons of inventories held by domestic uranium producers and fuel fabricators would extend the forward coverage by nine months (DOE 85a).

Secondary Market Transactions

The secondary market for uranium includes producer-to-producer sales, utility-to-utility sales and loans, and utility-to-producer sales. The secondary market, by definition, does not increase the supply of uranium, only the alternatives for purchasing it. As such, secondary transactions can have a significant impact on the demand for new production and on the year-to-year changes in inventories. The secondary market

EXHIBIT 2-5:

U.S. COMMERCIALLY-OWNED URANIUM INVENTORIES

AS OF DECEMBER 31, 1983 AND 1984

(Short Tons U_3O_8 Equivalent)

Owner Category	1982		1983		1984	
	Natural	Enriched	Natural	Enriched	Natural	Enriched
Utilities	49,550	18,950	46,600	32,050	47,950	31,800
Suppliers	18,550	350	16,900	350	11,450	500
TOTAL	68,100	19,300	63,500	32,400	59,400	32,300

Source: DOE 85b

has been significant in recent years. During 1983, sales of 2,600 tons of U_3O_8 equivalent were made between domestic utilities and suppliers in the secondary market. During 1984, this quantity decreased to 850 tons (DOE 85a).

2.1.2 Cost of Production

In 1984, the average cost of producing U_3O_8 from ore mined and milled in the United States was approximately $35 per pound (JFA 85a). Costs of production vary greatly among producers, however, ranging from $11.50 to $53.00 (Exhibit 2-6). Exhibits 2-7 and 2-8 list the 1977 costs of production, by cost element, for sample underground and open-pit mines. Capital costs for mill construction ranged from $1.99 to $3.98 per ton of ore processed, equal to 5.3 to 12.5 percent of the cost of production. Mill operating costs ranged from $5.41 to $10.16 per ton of ore, equal to 15.0 to 31.1 percent of production cost. Higher costs are generally associated with smaller capacity mines. The exhibits also show that milling costs are higher for low-grade deposits than for high-grade deposits, since the amount of ore that must be processed to yield a pound of U_3O_8 is greater for the former. Since the average grade of ore processed has decreased (from 0.154 in 1977 to 0.128 percent U_3O_8 in 1983), the share of production costs accounted for by milling has probably increased (Zi 79).

Reasonably assured resources[1] of uranium in each of 32 countries are listed, by cost category, in Exhibit 2-9. As the exhibit shows, while the U.S. has 20 percent of the total reserves, it accounts for only 9 percent of the lower cost reserves (less than $36 per pound). Five countries — Australia, Brazil, Canada, Niger, and South Africa -- have greater reserves in the lower cost category (OECD 83). In 198^ Canada and South Africa accounted for 90 percent of uranium imports (DOE 84a).

The differences in cost of production for the U.S. and other countries can be explained to a large extent by the grade of ore available in each country. The cost of producing uranium is largely a function of the grade of the ore in the ore body. Since the U.S.

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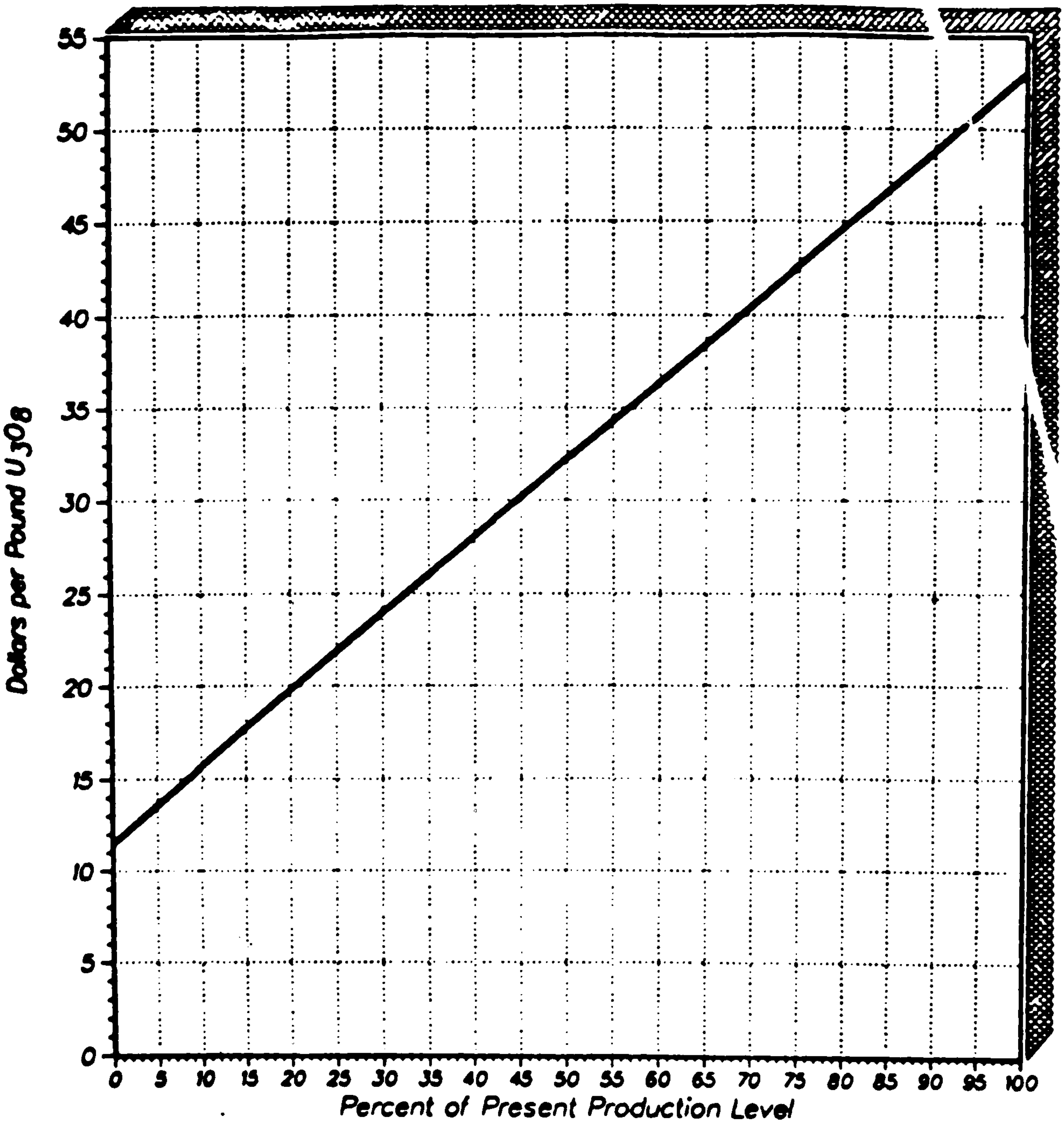
[1] Reasonably Assured Resources (RAR) include uranium in known mineral deposits of such size, grade, and configuration that it could be recovered within the given production cost ranges, with currently proven mining and processing technology. Estimates of tonnage and grade are based on specific sample data, measurements of the deposits, and knowledge of deposit characteristics. Reasonably Assured Resources have a high assurance of existence.

EXHIBIT 2-6:

LINEAR APPROXIMATION OF THE DISTRIBUTION OF 1983 AVERAGE COST OF U.S. URANIUM PRODUCTION



Source: DOE 84b

EXHIBIT 2-7:

COST ESTIMATES FOR URANIUM PRODUCTION FROM UNDERGROUND MINES WITH A DEPTH-TO-THICKNESS RATIO OF 76 AND AN ORE GRADE OF 0.25 PERCENT U_3O_8

(in dollars per short ton of ore, in 1977 dollars)

	Capacity (Short Tons of Ore Per Day)				
	500	1,000	2,000	3,000	5,000
Capital Costs					
Mine primary development	7.99	6.26	5.30	5.01	4.53
Mine plant and equipment	1.73	1.35	1.06	0.96	0.87
Mill construction	3.98	3.24	2.66	2.32	1.99
Subtotal	13.70	10.85	9.02	8.29	7.39
Operating Costs					
Mining	31.70	27.17	24.90	23.77	22.87
Hauling	1.73	1.73	1.73	1.73	1.73
Milling	10.16	7.87	6.56	5.90	5.65
Subtotal	43.59	36.77	33.19	31.40	30.25
Total	57.29	47.62	42.21	39.69	37.64

Source: Zi 79

EXHIBIT 2-8:
COST ESTIMATES FOR URANIUM PRODUCTION FROM OPEN-PIT MINES WITH A DEPTH-TO-THICKNESS RATIO OF 24 AND AN ORE GRADE OF 0.20 PERCENT U_3O_8

(in dollars per short ton of ore, in 1977 dollars)

	Capacity (Short Tons of Ore Per Day)				
	500	1,000	2,000	3,000	5,000
Capital Costs					
Mine primary development	10.77	9.54	9.18	9.09	8.92
Mine plant and equipment	0.35	.35	0.35	0.35	0.35
Mill construction	3.98	3.24	2.66	2.32	1.99
Subtotal	15.10	13.13	12.19	11.76	11.26
Operating Costs					
Mining	5.43	5.43	5.43	5.43	5.43
Hauling	1.41	1.41	1.41	1.41	1.41
Milling	9.92	7.62	6.31	5.65	5.41
Subtotal	16.76	14.46	13.15	12.49	12.25
Total	31.86	27.59	25.34	24.25	23.51

Source: Zi 79

EXHIBIT 2-9:

REASONABLY ASSURED RESOURCES

(1,000 Tons of Uranium)

Data available January 1, 1983

Countries	Cost Range Less than $36/lb	$36-$59/lb	Total
Algeria[b,e]	26	—	26
Argentina[b]	18.8	4.5	23.3
Australia	314	22	336
Austria[e]	0	0.3	0.3
Brazil[a]	163.3	—	163.3
Cameroon, Republic of	0	0	0
Canada	176	9	185
Central African Republic[a,d]	18	—	18
Chile[a,g]	0	2.3	2.3
Denmark	0	27	27
Egypt	0	0	0
Finland[a]	0	3.4	3.4
France	56.2	11.3	67.5
Gabon	18.7	4.7	23.3
Germany, Federal Republic of	0.9	4.2	5.1
Greece	0.4	0	0.4
India	31.7	10.9	42.6
Italy	2.9	—	2.9
Japan	7.7	—	7.7
Korea, Republic of	0	10	10
Mexico[a]	2.9	—	2.9
Namibia[e]	119	16	135
Niger[b,c]	160	—	160
Peru[a]	0.5	—	0.5
Portugal	6.7	1.5	8.2
Somalia[a,d]	0	6.6	6.6
South Africa	191	122	313
Spain	15.7	4.5	20.2
Sweden[f]	2	37	39
Turkey[a]	2.5	2.1	4.6
United States of America	131.3	275.9	407.2
Zaire[b,c]	1.8	—	1.8
TOTAL (rounded)	1,468	575	2,043

[a] Uranium contained in-situ.

[b] Uranium contained in mineable ore.

[c] OECD (NEA)/IAEA: "Uranium Resources, Production and Demand," Paris, 1977.

[d] OECD(NEA)/IAEA: "Uranium Resources, Production and Demand," Paris, 1979.

[e] OECD(NEA)/IAEA: "Uranium Resources, Production and Demand," Paris, 1982.

[f] Includes 35,000 tons uranium in the Ranstad deposit from which no uranium production is allowed due to a veto by local authorities for environmental reasons.

[g] Assigned to cost category by OECD.

Source: OECD 83

has lower grade ore than many other large producing countries, it suffers a disadvantage in costs (JFA 85). A dramatic example of this competitive disadvantage is provided by comparing the quality of Canadian and U.S. ore. According to a 1984 article in Chemical Week, a ton of Canadian ore yields 40 to 60 pounds of U_3O_8, while a ton of U.S. ore yields only four pounds (CW 84).

2.2 DEMAND

Domestic uranium mill operators have two markets for their production: the U.S. nuclear power industry and exports. The nuclear power industry is by far the more important of the two. In 1984, 1,100 tons of U_3O_8 were exported, and current commitments for exports total only 3,850 tons for 1985-2000 (DOE 85a). Military uses, once the only source of demand for uranium, have been supplied solely by government stockpiles since 1970 (DOE 84a).

Demand for domestic uranium has declined for the past five years. In 1979, utilities delivered 15,450 tons of domestic uranium oxide to DOE for enrichment, 42 percent more than 1983 deliveries. Exports too have declined substantially. In 1979, exports amounted to 3,100 tons, almost three times as much as in 1984. A number of negative forces have combined to cause the current depressed state of the industry. Perhaps most importantly, the growth in electricity generated by nuclear plants and the expansion of nuclear power capacity has been much slower than had been forecasted in the mid 1970's due in part to numerous construction delays and cancellations. Second, as discussed in Section 2.1, imports have begun to play a major role in the U.S. uranium market. The import restrictions in effect from 1964 to 1977 have undergone a phased withdrawal, and as of 1985 there are no import limitations. The result has been a steady increase in uranium imports from nations possessing high grade (and thus low cost) uranium deposits. Expectations are that a growing portion of utility requirements will be supplied by foreign-origin uranium during the second half of this decade (JFA 85).

A third factor contributing to the current downturn in the uranium industry, also discussed in Section 2.1, is the large inventories being held by both producers and utilities. Utilities, anticipating a growing need for uranium, entered into long-term contracts to purchase large amounts of domestically produced uranium. As actual needs fell short of expected needs due to nuclear power plant construction delays and cancellations, large inventories began to accumulate. These inventory supplies, currently estimated to cover four to five years of utility requirements, adversely affect suppliers in two ways. They may extend the downturn in uranium demand for a number of years by decreasing utility needs to enter new contracts. Also, high interest rates have increased inventory holding costs, leading some utilities to contribute to current excess supply by offering inventory stocks for sale on the spot market (JFA 85a).

The focus of the remainder of this section is on total U.S. demand for uranium, not just on demand for domestic production or production from conventional mills. The first subsection details historical uses of uranium. The concluding subsection provides a brief description of uranium prices and pricing mechanisms.

2.2.1 Uranium Uses

Military Applications

In the early 1950's, the U.S. government's need for uranium for defense uses far exceeded the world's production capability. A federally funded production incentives program was then instituted. The incentives program was so effective that the government phased it out in the 1960's and terminated its purchase program in 1970. The government still has sufficient stockpiles to meet military requirements well into the future.

Though Federal consumption data are not available to the public, apparent consumption can be estimated from analysis of changes in stockpiles. Stocks held by the Department of Energy between 1982 and 1984 were as follows:

	Thousand Short Tons of U_3O_8 Equivalent		
	Natural Uranium	Enriched Uranium	Total Uranium
January 1, 1984	20.30	57.45	77.75
January 1, 1983	20.50	58.10	78.60
January 1, 1982	20.50	59.20	79.20

Inventory drawdown equaled 600 short tons in 1982, and 850 short tons in 1983. As the government is not believed either to buy or sell uranium currently, inventory drawdown is assumed equal to government consumption (DOE 84a).

Nuclear Power Plants

Since 1971, utilities, which use uranium as fuel for nuclear power plants, have been virtually the only source of demand for current uranium production. Commercial generation of nuclear powered electricity began in 1957 with the operation of the first central station reactor at Shippingport, Pennsylvania. At the end of 1983, 80 nuclear reactors were licensed to operate in the United States, totaling 64.4 gigawatts of generating capacity (DOE 84c)

Demand for uranium by utilities may be directly linked to the fuel requirements of currently operating or planned nuclear power plants. The status of U.S. nuclear power plants as of June 30, 1985 is shown in Exhibit 2-10. Because of the long lead times associated with the ordering, construction and permitting of nuclear power plants it is extremely unlikely that any additional orders for new nuclear plants will result in operable capacity before 1996 (DOE 85c).

Historical consumption data for utilities are not available. The closest approximation is statistics on deliveries by utilities of uranium to DOE enrichment plants. Deliveries for 1977 to 1984 are listed in Exhibit 2-11.

Exports

Exports of uranium by producers have declined in every year since 1979. In 1984, at 1,100 tons of U_3O_8, they were at their lowest level since 1976. Current commitments for exports total only 4,400 tons for 1985-2000 (DOE 85b). Exports for the years 1967-1984 are shown in Exhibit 2-12.

2.2.2 Pricing

Two basic types of pricing arrangements dominate the procurement of uranium: contract pricing and market pricing. In procurements with contract pricing, prices and their escalation factors, if any, are determined when the contract is signed. In procurements with market pricing, the price is commonly determined just before delivery and is based on the market price prevailing at that time. Some market price contracts contain a floor price, set at the time the contracts are signed, that serves as a minimum on the eventual settled price. Pricing arrangements that cannot be

EXHIBIT 2-10:

STATUS OF U.S. NUCLEAR POWER PLANTS

AS OF JUNE 30, 1985

Status	Number of Reactors	Net Design Capacity (GWe)
Operable		
In Commercial Operation	86	71.1[a]
In Power Ascension.	5	6.0
Total[b]	91	77.0
In Construction Pipeline		
In Low-Power Testing	4	4.1
Under Construction.	26	29.7
Indefinitely Deferred	7	7.3
Canceled, With Extension of Construction Permit Requested	1	1.1
Total	38	42.2
Reactors on Order	2	2.2
Total	131	121.4

[a]Includes Three Mile Island 1 (819 MWe), which has an operating license but remained in an extended shutdown mode at publication time. Three Mile Island 2, Dresden 1, and Humboldt Bay are not included.

[b]Total capacity may not equal sum of components, due to independent rounding.

Source: DOE 85c

EXHIBIT 2-11:
DELIVERIES OF URANIUM TO DOE ENRICHMENT PLANTS BY DOMESTIC UTILITIES

Year	Amount Delivered (Short Tons U_3O_8) U.S. Origin	Foreign Origin	Total
1977	14,250	700	14,950
1978	11,950	750	12,700
1979	15,450	1,600	17,050
1980	11,150	1,200	12,350
1981	10,050	1,150	11,200
1982	13,550	3,000	16,550
1983	10,850	2,200	13,050
1984	8,400	5,750	14,150

Sources: DOE 84a, DOE 85b

EXHIBIT 2-12:

EXPORTS OF URANIUM[a]

(Thousand Short Tons of U_3O_8)

Historical Exports		
Year	Total Exports	Producer Exports
1967	N.A.	0.7
1968	N.A.	0.8
1969	N.A.	0.5
1970	N.A.	2.1
1971	N.A.	0.2
1972	N.A.	0.1
1973	N.A.	0.6
1974	N.A.	1.5
1975	N.A.	0.5
1976	N.A.	0.6
1977	N.A.	2.0
1978	N.A.	3.4
1979	N.A.	3.1
1980	N.A.	2.9
1981	N.A.	2.2
1982	3.10	2.2
1983	1.65	N.A.
1984	1.10	N.A.

[a]Total exports include exports by utilities, producers and other suppliers (reactor manufacturers and fuel fabricators). Data for exports by utilities and other suppliers were not collected prior to 1982.

N.A. = Not Available.

Sources: DOE 84a, DOE 85a

classified as either market or contract pricing are grouped in a third category. This "other" category refers primarily to supply arrangements wherein the buyer has direct control of a uranium property. Among 1983 deliveries of uranium, 41 percent used contract pricing, 55 percent used market pricing, and four percent used "other" pricing arrangements (DOE 84a).

The concept of market pricing is probably the most complex of the three types. While it is common to refer to a "market" or "spot" price for uranium, there is actually no centralized spot or futures market. Contracts are negotiated either between a producer and a utility, through a middleman such as a nuclear power plant manufacturer, or through a broker. The price commonly referred to as the "spot price" for uranium is a price published by the Nuclear Exchange Corporation (NUEXCO), the principal uranium broker. This price, which NUEXCO calls the uranium "exchange value" is a monthly estimate of the price at which transactions for immediate delivery could have been concluded as of the last day of the month (DOE 83).

Historical Prices and Pricing Mechanisms

Prior to 1968, prices were largely determined by the Atomic Energy Commission. In the early years of the commercial uranium market, 1968 through 1973, the price of uranium declined and remained low despite conditions of excess long term demand. Beginning in 1973 the price of uranium jumped due to immediate industry requirements, a surge in long term contracting due in part to changes in procedures for enrichment service contracts, and other factors.

At the same time, the terms under which long-term contracts were priced began to change. Until 1973 contracting was typically under fixed price contracts with inflation provisions. However, in 1973 producers resisted signing fixed price contracts because, due to production cost increases, they were losing money on previous fixed price contracts and because they anticipated price rises in the future. In 1974, when uranium became a seller's market, market price contracts became increasingly popular. These contracts were written to guarantee the producer a base rate-of-return on investment. In a short time, market price contracts became the norm.

In 1979-1980, the sellers' market for uranium ended and the uranium market witnessed a sharp decline in prices due to postponements and cancellations of nuclear reactors, the build-up of uranium inventories at utilities, and growing competition from low-priced imported uranium. A sharp decline in the nominal price of uranium began in 1980, dropping from over $40 per pound of U_3O_8 at the end of 1979 to $23.50 per pound by August 1981. In real terms (adjusted for inflation) the price had actually begun dropping in 1976. The price in August 1981 in constant dollars was half of what it had been in 1976. The price has continued to drop slowly from 1980 through 1984 (DOE 83). Historical average contract prices and floor prices of market price contracts are provided in Exhibit 2-13. Historical NUEXCO exchange values, or "spot prices" are listed in Exhibit 2-14.

Prices of Foreign-Origin Uranium

Prices of imported uranium are substantially lower than domestic prices. The average price paid for 1983 deliveries of imported uranium was $26.16 per pound of U_3O_8, approximately one-third less than the amount paid for domestic-origin uranium (DOE 84a). Exhibit 2-15 shows the weighted average price paid by domestic customers for 1981 to 1983 deliveries of foreign-origin uranium and projected prices for 1984 deliveries.

2.3 INDUSTRY STRUCTURE AND PERFORMANCE

The number of firms participating in the domestic uranium milling industry has declined in recent years. In 1977, there were 26 companies that owned active uranium mills. In 1983, the number had fallen to 11, and by June 1985, there were only 2 (DOE 84b; PEI 85a). The contraction of the industry can also be seen in trends in employment and capital expenditures (Exhibit 2-16). Capital expenditures in 1984 were only $4 million, compared to $287 million in 1979 (1984 dollars) (DOE 85a; DOE 84a). Employment in 1984 was a low 987 person-years, compared to 3236 person-years in 1979 (DOE 85b; DOE 80).

2.3.1 Mill Capacity and Output

Mining and milling production data for individual companies are collected by DOE but are not available to the public. However, some aggregate data are published. During 1984, the top 4 firms accounted for 55 percent of mill output, and the top 8 for 87 percent (DOE 85a). Mill capacities by firm and mill are listed in Exhibit 2-17.

EXHIBIT 2-13:

AVERAGE CONTRACT PRICES AND FLOOR PRICES OF MARKET PRICE CONTRACTS BY YEAR OF CONTRACT SIGNING

(January 1984 Dollars Per Pound of U_3O_8)

Year Of Signing	Average Contract Price	Average Floor Price	Combined Average Contract and Floor Price[a]
1975	41.72	43.10	42.47
1976	63.33	60.68	61.01
1977	50.30	55.39	53.76
1978	43.70	51.22	45.56
1979	34.81	43.25	35.18
1980	40.74	47.25	43.11
1981	22.36	23.84	22.73
1982	28.36	NR	28.36
1983	29.56	26.00	29.03

[a]Prices are weighted averages.

NR = None reported.

Source: DOE 84a

EXHIBIT 2-14:

HISTORICAL NUEXCO EXCHANGE VALUES

(Nominal Dollars Per Pound of U_3O_8)

Year	Nominal Dollars Per Pound of U_3O_8 As of December 31
1968	5.50
1969	6.20
1970	6.15
1971	5.95
1972	5.95
1973	7.00
1974	15.00
1975	35.00
1976	41.00
1977	43.00
1978	43.25
1979	40.75
1980	27.00
1981	23.50
1982	20.25

Source: PNL 84

EXHIBIT 2-15:
PRICES FOR FOREIGN-ORIGIN URANIUM
AS OF JANUARY 1, 1984

Year	Quantity-Weighted Average Price Per Pound of U_3O_8 (Year-of-Delivery Dollars)	Amount of U_3O_8 (Thousand Short Tons)	Percentage Of Total Import Delivery Commitments Sampled
1981	32.90	2.20	67
1982	31.05	2.00	53
1983	26.16	4.10	100
1984	27.39	3.25	70

Sources: DOE 84a, DOE 82

EXHIBIT 2-16:

CAPITAL EXPENDITURES, EMPLOYMENT, AND ACTIVE MILLS: CONVENTIONAL URANIUM MILLING INDUSTRY

	Capital Expenditures (million constant 1984 $)	Employment (Person-Years)	Active Number of Mills At Year-End	Production (Short Tons)
1979	281	3,236	N/A	16,877
1980	307	3,251	N/A	18,903
1981	68	2,367	20	15,998
1982	12	1,956	14	10,447
1983	3	1,518	12	7,760
1984	4	987	8	4,813

N/A = not available

Sources: DOE 85a, DOE 85b, DOE 80

EXHIBIT 2-17:

OPERATING STATUS AND CAPACITY OF LICENSED CONVENTIONAL URANIUM MILLS AS OF AUGUST 4, 1986[a]

State	Mill	Owner	Operating Status[b]	Operating Capacity (tons/day)[c]
Colorado	Canon City	Cotter Corp.	Standby	1200
	Uravan	Umetco Minerals	Standby	1300
New Mexico	L-Bar	Sohio/Kennecott	Decommissioning[d]	1650
	Churchrock	United Nuclear	Decommissioning[d]	4000
	Bluewater	Anaconda	Decommissioning[d]	6000
	Quivira	Kerr-McGee	Standby	7000
	Grants	Homestake	Active[e]	3400
South Dakota	Edgemont	TVA	Decommissioned	—
Texas	Panna Maria	Chevron	Active	2600
	Conquista	Conoco/Pioneer	Decommissioned	—
	Ray Point	Exxon	Decommissioned	—
Utah	White Mesa	Umetco Minerals	Active[f]	2000
	La Sal	Rio Algom	Active[g]	750
	Moab	Atlas	Standby	1400
	Shootaring Canyon	Plateau Resources	Standby	800
Washington	Ford	Dawn Mining	Standby	600
	Sherwood	Western Nuclear	Standby	2000
Wyoming	Highland	Exxon	Decommissioned	—
	Gas Hills	American Nuclear Corp.	Decommissioned	—
	Shirley Basin	Petrotomics	Decommissioned	—
	Gas Hills	Pathfinder	Standby	2500
	Split Rock	Western Nuclear	Standby	1700
	Gas Hills	Umetco Minerals	Standby	1400
	Bear Creek	Rocky Mt. Energy	Decommissioning[d]	2000
	Shirley Basin	Pathfinder	Active	1800
	Sweetwater	Minerals Exploration	Standby	3000
Total			5 Active 11 Standby 10 Decommissioned or intend to decommission	

(a) Data obtained from conversations with Agreement States, NRC representatives, and mill operators. Does not include mills licensed but not constructed.

(b) Active mills are currently processing ore and producing yellowcake. Standby mills are not currently processing ore, but are capable of restarting. The mill structure has been dismantled at decommissioned mills and tailings piles are currently undergoing reclamation or will be.

(c) Tons indicates short tons equal to 2000 lbs.

(d) Submitted letter of intent to decommission

(e) Operating only a few days each month.

(f) Current contract will allow operation for 12-18 months.

(g) Likely to go to standby status.

A wide variety of companies are represented within the uranium industry. In the industry's early years, holdings were dominated by independent mining and exploration companies. Since then, mergers, acquisitions, and the entry of conglomerates have considerably altered industry structure. During the 1970's the oil embargo and optimistic forecasts of future nuclear power capacity made entry into the uranium market attractive to oil companies and utilities. Of the 17 companies that owned mills in 1984, ten were subsidiaries of oil companies, utilities, or large chemical companies; one was a subsidiary of a transportation company; and six were mining corporations. For the most part, uranium activities are a small part of the owners' business. This influences the long-term outlook for the stability of the industry since large, diversified companies are likely to have the financial resources to weather the current downturn in the market if they expect a return to profitability.

2.3.2 Employment Analysis

Department of Energy estimates of employment in the uranium milling industry in 1984 are listed in Exhibit 2-18. Additional detail at the State level was obtained through discussions with staff of the departments of mining or natural resources in the States with uranium mills. This is provided in the following paragraphs.

Historically, New Mexico and Wyoming have been the nation's leading producers of uranium and have jointly been responsible for an estimated 70 to 75 percent of total uranium concentrate production. Following the peak production period of 1981 and 1982, and since the onset of the production decline in the latter part of 1982, it is estimated that approximately 7000 jobs have been lost in New Mexico as production fell from 253 million tons in 1982 to 36 million in 1984 (NM 85).[1]

Exhibit 2-19 contains a description of uranium milling activity in the State of Wyoming. It reveals that there were seven uranium mine-mill complexes and one uranium mill in 1980 collectively employing 2451 people. In 1981, there were seven mills and mine-mill complexes employing 1361 people. In 1984, data were available for five mine-mill

[1] Employment and output estimates provided by State sources may not agree with those provided by the U.S. Department of Energy and presented elsewhere in this report, due to differences in data collection procedures.

EXHIBIT 2-18:

EMPLOYMENT IN THE U.S URANIUM MILLING INDUSTRY

BY STATE, 1984

State	Person-Years Expended
Colorado	215
Wyoming	310
Arizona, New Mexico, Texas, Utah, Washington	462
TOTAL	987

Source: DOE 85b

EXHIBIT 2-19:
URANIUM MILLING ACTIVITY IN THE STATE OF WYOMING

Name of Operator	Name of Mine	County and Location	Facilities	No. of Employees 1980	1981	1984	Production (Tons) 1980	1981	1984
Bear Creek Uranium Co.	Beer Creek Mine	Natrona	Surface Uranium Mine and Mill Complex	258	232	160	539,000	625,000	448,464
Federal American Partners	Milling Plant [1/]	Fremont	Uranium Mill Engineering and Exploration	100	135	--[2/]	500	411,292	--
Minerals Exploration Corporation	Sweetwater Uranium Project	Sweetwater	Open Pit Uranium Mine and Mill	267	254	8	395,585	1,026,841	0
Pathfinder Mines Corporation	Luck McMine and McMill	Fremont	Open Pit Uranium Mine and Mill	491	107	73	McMill 190,416 McMine 631,213	McMill 619,580	McMill- 589,874 yellow cake
Pathfinder Mines Corporation	Shirley Basin Mine	Carbon	Open Pit Uranium Mine, Mill and Maintenance Shop	556	403	141	1,086 yellow cake	466,348	85,216
Petro-tronics Company	Petronics tronics Mine and Mill	Carbon	Open Pit Uranium Mine and Mill	515	--	44	1,736,865	--	275,103 yellow cake
Western Nuclear Inc.	McIntosh Pit	Fremont	Open Pit Uranium Mine and Mill	38	--	--	221,796	--	--
Western Nuclear	Split Rock Mill	Fremont	Open Pit Uranium Mines and Mill	226	147	22	586,102	206,521	0
Getty Oil Company	Petro tronics Mill	Carbon	Uranium Mill	--	83	--	--	465,365	--
Total: 'Milled' and Mined and Milled" (tons)							3,671,350	3,820,947	1,398,657
Total: No.of Employees engaged in 'mining and milling'				2451	1361	454			

	Percentage Change 1980-84
Total: 'Milled' and 'Milled and Mined	-62%
Total: No.of employees engaged in 'mining and milling' and milling'	-81%

NOTES:

1. The 1981 data were found under the name "Federal American Mine" which operated the following facilities: underground mine; open-pit mine and uranium extraction mill.
2. "--"indicates data not found, which might suggest the closure of a mill. By contrast, an entry of zero might serve as an indication that the mill was still operational.

SOURCES: Wyoming State Inspector of Mines; 1980, 1981 and 1984 complexes and one mill, and only four of these operations recorded any output. Employment was down to 454 workers. Thus, from 1981 to 1984, the total number of individuals employed at mills and mine-mill complexes declined by 81 percent and production declined by approximately 6 percent (WY 80, 81, and 84).

In the State of Washington, before 1982 there were two mine-mill complexes: Midnight mines (owned and operated by Dawn Mining Company) and the Sherwood Mine (owned by Western Nuclear, a subsidiary of Phelps Dodge Corporation). In 1981, Dawn employed 50 workers, and in 1982 it employed 42. In 1981, Sherwood employed 45 workers, while in 1982 it employed 14 miners plus 98 maintenance workers. Both mine-mill complexes are currently inactive and unemployment (estimated at 40 percent from 1982 to 1983) was estimated to be as high as 80 percent (WA 85).

In Colorado, there were 508 mineral industry operations in 1980, 100 of which were engaged in the production of uranium. By 1985 however, there were only two mines or mine/mill complexes: Centennial and Schwartzwalder. In 1980, the uranium industry employed approximately 1594 individuals (Nugent 80), whereas it is estimated that the two operations now employ about 200 people (Co 85).

In Texas, there were until recently, three mills: the Conquista Project (Conoco), Ray Point (Exxon) and the Panna Maria complex (Chevron). The Conquista complex, it is estimated, employed over 500 people during its peak period from 1979 to 1980, and the Panna Maria complex about 250 people during its peak period from 1981 to 1983. The Conquista Project and Ray Point have now been decommissioned. The Panna Maria complex maintains a skeleton staff of seven to eight people (TX 85).

2.3.3 Community Impact Analysis

The impact of trends in uranium milling on small communities dependent on uranium milling facilities tends to vary depending on the location of the mines; the importance of uranium mining and milling to the state; and the nature of the workforce. Texas and Washington are on opposite sides of the dependency spectrum, and therefore serve as interesting case studies.

In the State of Washington, the uranium facilities are located primarily in the Spokane Indian Reservation. Mining soon became the main economic activity as the mining companies were under contractual obligation to draw 51 percent of their labor force from the Indian community. When the two Washington mine-mill complexes, Midnight Mines and Sherwood Mines, closed in 1983-1984, the unemployment rate rose to about 80 percent. This is perhaps partly attributable to the absence of any other mining activity on the reservation which might have absorbed some of the displaced workers. This high unemployment rate also suggests limited mobility on the part of miners and workers. Thus, in the case of Washington it would seem that the employment effects were concentrated, and felt largely by the Indian community which served as the principal source of labor for uranium mining and milling within the state (WA 85).

In Texas, in contrast, the community impacts of the uranium industry are less significant. Most uranium industry employees were originally farmers and ranchers, maintaining and upgrading their properties during the lifetime of their mining careers. Moreover, they were mostly a commuting workforce so there was no residual pool of unemployed persons in the vicinity of the mines once the decline in employment took place in the 1980's. There were no uranium mining communities as such in the State of Texas which were dependent on the mining and production of uranium for their subsistence. Moreover, many workers were absorbed by the booming petroleum and lignite industries (TX 85).

In the case of both Colorado and Utah, the ability to absorb unemployed uranium workers is limited. In Colorado this has been due to the depressed state of the mining industry in general within the State (CO 85). In New Mexico, where uranium mining and milling are considered an important economic activity, there were areas of concentrated impact - such as Gallup, the Laguna Pueblo area and the Navajo Indian Reservation. The wide scale reduction in employment observed in recent years, the reduction in sales and sales tax revenues, the loss of severance payments, a significant amount of out-migration to Nevada and several other states, and a concomitant reduction in income tax revenue have combined to make the impact significant and state-wide as opposed to community-specific (NM 85).

2.3.4 Financial Analysis

Selected financial data for the domestic uranium industry for 1980 to 1984 are shown in Exhibit 2-20. The data cover a subset of firms (the same firms for all years) that represent over 80 percent of the assets in the industry in each year. The firms included are those for which uranium operations could be separated from other aspects of the organization's business, and for which an acceptable level of consistency in financial

EXHIBIT 2-20:

FINANCIAL STATISTICS OF THE DOMESTIC URANIUM INDUSTRY, 1980-1984 — (Continued)

(Million Dollars)

	1980	1981	1982	1983	1984
Income Statement					
Operating Revenues	999.3	1,067.5	888.9	767.7	525.8
Operating Income (Loss)	4.5	62.1	(43.5)	73.4	(10.0)
Net Income (Loss)	(11.0)	40.8	(15.9)	37.8	(205.5)
Source and Use of Funds Statement					
Net Income (Loss)	(11.0)	40.8	(15.9)	37.8	(205.5)
Depreciation, Depletion, and Amortization	138.2	170.8	225.3	152.5	97.4
Deferred Taxes	38.3	22.7	(22.6)	1.5	(65.6)
Debt and Equity	275.0	296.4	352.8	21.4	16.5
Other Sources	263.3	98.1	118.6	174.2	441.1
Total Sources	703.6	628.8	658.2	387.4	283.9
Capital Expenditures (Property, Plant, and Equipment)	464.1	297.3	122.2	61.5	29.1
Debt Repayment	28.4	167.9	93.1	53.4	72.5
Other Uses	155.9	101.7	354.2	234.7	109.2
Total Uses	648.4	566.9	569.5	349.6	210.8
Change in Working Capital	55.4	61.9	88.7	37.8	73.1
Balance Sheet					
Current Assets (Less Inventory)	249.2	220.9	253.2	261.5	393.2
Inventory	255.5	331.0	381.4	292.7	356.6
Net PP&E	2,065.0	2,293.7	2,106.1	1,546.9	1,351.0
Other Noncurrent Assets	350.4	263.4	431.8	553.8	351.7
Total Assets	2,920.1	3,109.0	3,172.5	2,654.9	2,452.5
Current Liabilities	246.0	221.8	193.4	147.5	304.9
Deferred Liabilities	1,378.1	1,542.2	1,441.4	1,544.6	1,321.4
Total Liabilities	1,624.1	1,764.0	1,634.8	1,692.1	1,626.3
Equity	1,296.0	1,345.0	1,537.7	962.8	826.2
Total Liabilities and Equity	2,920.1	3,109.0	3,172.5	2,654.9	2,452.5

EXHIBIT 2-20:

FINANCIAL STATISTICS OF THE DOMESTIC URANIUM INDUSTRY, 1980-1984

(Million Dollars) — (Continued)

	1980	1981	1982	1983	1984
Ratios (percent)					
Rates of Return					
Net Income to Total Asstes.	-0.4	1.3	-0.5	1.4	-8.4
Net Income to Total Equity.	-0.8	3.0	-1.0	3.9	-24.9
Net Income to Net Investment in Place	-0.5	1.8	-0.8	2.4	-15.2
Fund Flow Measures					
Additions to PP&E to Total Sources of Funds.	65.9	47.3	18.6	15.9	10.3
Leverage Measures					
Deferred Liabilities to Total Equity	106.3	114.7	93.7	160.4	159.9
Deferred Liabilities to Total Assets	47.2	49.6	45.4	58.2	53.9
Liquidity Measures					
Current Ratio	2.1	2.5	3.3	3.8	2.5
Liquidity Ratio	1.0	1.0	1.3	1.8	1.3

Source: DOE 85a

reporting practices was available for all years. Financial data on the milling industry alone are not available.

As shown in the exhibit, net income accruing to the uranium industry was positive in only two years, 1981 and 1983. The returns on assets (net income divided by total assets) in these years were 1.3 and 1.4 percent respectively, and aggregate net earnings totalled $78.6 million. In 1980, 1982 and 1984, the returns on assets were -0.4, -0.5, and -8.4 percent, and aggregate net losses reached $232.4 million. The loss in 1984 alone was $205.5 million on revenues of $525.8 million. Thus, the aggregate loss for the five years was $153.8 million. Compared to the rest of the economy, the uranium industry's situation appears even worse: for the period 1980-1984, the annual growth in after-tax corporate profits for the total domestic economy averaged 19.3 percent.

The industry's financial picture in 1984 stemmed largely from the need for restructuring of its asset base in response to the continuing decline in the market for uranium. Many uranium properties and facilities were written down in 1984 to reflect the present value of the revenues from contracted future deliveries of uranium. During 1984, an amount well in excess of $200 million was charged against income in the writedown process. The adjustment will permit most to be more competitive in the future (DOE 85a).

Company-specific information on uranium production, revenues, profits, and plans is provided in the following paragraphs.

Kerr-McGee Corporation

Kerr-McGee has been a major domestic uranium producer since it first entered the industry in 1952. In October of 1983, the company split its uranium operations into two divisions, Quivira Mining Company and Sequoyah Fuels Corporation. Quivira became the uranium mining and milling subsidiary, operating two mining complexes and processing the ore at the nation's largest (7000 ton per day) mill, in Grants, New Mexico. Sequoyah Fuels operates a facility in Oklahoma that is one of only two plants in the U.S. that converts U_3O_8 into uranium hexafluoride (UF_6) and also produces uranium concentrate from solution mining in Wyoming.

In January 1985, Kerr-McGee placed its mines and mill on standby. The uranium operations, which have been for sale for some time, have been written down in value in

Kerr-McGee's financial statements, by $42 million after taxes, to the present value of existing contracts. Contractual commitments will be met through inventory and mine-water recovery techniques (AR 84a, AR 83a). Statistics on Kerr-McGee's uranium operations are provided in Exhibit 2-21.

Homestake Mining Company

Homestake Mining Company owns two conventional uranium mines and a 3400 ton per day mill in Grants, New Mexico. During 1984, production of uranium was reduced to the minimum level at which satisfactory unit costs could be maintained. Mine production was confined to one mine operating on a five-day-week schedule for ten months of the year. Uranium concentrate was also recovered from solution mining and ion-exchange. In 1984, uranium accounted for 18 percent of the company's revenues, and a disproportionate 31 percent of operating earnings, for a return on operations of 34 percent. The high return for the vear is attributed to existing contracts which provide for sale prices above current spot prices and production costs. In 1982 and 1983, in comparison, the returns on uranium operations were 24 and 19 percent, respectively. Operating returns for all Homestake operations during 1982-1984 were 23, 26 and 20 percent, respectively.

During 1985, the company suspended its conventional mining and milling operations and expanded its uranium leaching facilities. Uranium earnings are expected to continue to decline in the next two years with the expiration of existing sales contracts (AR 84b). Financial information for Homestake's uranium operations is presented in Exhibit 2-22.

Rio Algom

Rio Algom is a Canadian corporation engaged in the mining of a wide variety of materials, including copper, steel, and uranium. In 1983, uranium operations accounted for 38 percent of corporate revenue, but most (94 percent) was from Canadian production. In the United States, the company owns two uranium mines and a 750 ton per day mill in La Sal, Utah.

In 1983, the company produced 167 tons of uranium oxide from its Utah mines, and delivered 150 tons under a new contract secured for the years 1983-1986. The mines operated at approximately 50 percent of capacity in 1983, while the mill operated at

EXHIBIT 2-21(a): KERR-MCGEE CORPORATION URANIUM OPERATIONS: FINANCIAL DATA, 1982-1984[1]

(million $)

	1984	1983	1982
Sales	$ 90	$ 115	$ 153
Operating Income	($ 67)	($ 6)	$ 20
Assets	$ 182	$ 288	$ 313
Depreciation, Depletion	$ 14	$ 15	$ 16
Capital Expenditures	$ 1	$ 4	$ 7

EXHIBIT 2-21(b): KERR-MCGEE CORPORATION URANIUM OPERATIONS: RESERVES, PRODUCTION, PRICES, AND DELIVERIES, 1980-1984[1]

	1984	1983	1982	1981	1980
Reserves (demonstrated, 1000 tons)	98,236	100,589	102,551	105,894	114,116
Ore Milled (1000 tons)	531	700	N/A	N/A	N/A
Production (U_3O_8, 1000 pounds)	1,890	2,330	4,181	5,042	5,627
Average Market Price/lb of U_3O_8	$30.28[2]	$ 27.29	$ 28.12	$ 28.12	$ 28.61
U_3O_8 Delivered (1000 pounds)	1,228	2,708	3,942	5,354	6,751

[1]Includes both data for both Quivira Mining Company and Sequoyah Fuels Corporation.

[2]Current year sales prices are not representative since they are primarily related to prior year fixed price contracts.

N/A = not available

Sources: AR 84a, AR 83a

EXHIBIT 2-22:
HOMESTAKE MINING COMPANY URANIUM OPERATIONS
1982-1984

	1984	1983	1982
Revenues (millions)	\$ 57.9	\$ 58.6	\$ 63.7
Operating Income (millions)	\$ 19.6	\$ 11.4	\$ 15.6
Sales of U_3O_8 (million pounds)	1.130	1.130	N/A
Sales Price Per Pound of U_3O_8[1]	\$ 51.21	\$ 49.76	\$ 46.15
Depreciation, Depletion, and Amortization (millions)	\$ 4.4	\$ 14.3	\$ 20.0
Additions to Property, Plant, and Equipment (millions)	\$ .7	\$ 0.0	\$ 1.0
Identifiable Assets (millions)	\$ 66.9	\$ 73.0	\$ 80.8

[1]Prices based on long-term contracts which expire in 1986 and 1987.

N/A = not available.

Source: AR 84b

capacity due to a significant amount of toll milling (AR 83b).[1] The company closed one mine in early 1985, and may soon place its mill on standby (PEI 85a).

Selected financial statistics on Rio Algom uranium operations are presented in Exhibit 2-23.

Plateau Resources Limited

Plateau Resources, a wholly owned subsidiary of Consumers Power Co., was organized in 1976 to acquire, explore, and develop properties for the mining, milling, and sale of uranium. All operations were suspended in 1984 because of depressed demand and assets were written down by about $46 million after taxes, to an estimated net realizable value of approximately $55 million. There is no assurance that the amount will ever be realized however. The company's 800 ton per day mill at Ticaboo, Utah, which was constructed in 1980 and 1981, has never been active (AR 84c).

Western Nuclear

Western Nuclear, a subsidiary of Phelps Dodge Corporation, owns two mine and mill complexes, one in Wyoming and one in Washington. The capacities of its mills are 1700 and 2000 tons per day, respectively. The Wyoming mill has been on standby since the early 1980's, and decommissioning is anticipated. The Washington complex operated intermittently from 1981 through 1984. In late 1984, Phelps Dodge wrote off its entire "Energy" operation, of which Western Nuclear is a major part. While the company believes that nuclear power will ultimately have an important role in satisfying the nation's energy needs, Phelps Dodge has suffered other financial losses that made it necessary to dispose of operations that have uncertain prospects for near-term profitability. Contracts to deliver 400 tons of uranium oxide in 1984 and 422 tons in 1985 were expected to be fulfilled primarily with purchases from the spot market instead of new production. Exhibit 2-24 provides data on Phelps Dodge's U_3O_8 production and ore reserves, plus financial information on Phelps Dodge's "Energy" operations, which include a gas and oil subsidiary in addition to uranium operations (AR 83c, AR 84d).

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[1] "Toll milling" is the processing of ore from another company's mines on a contract basis.

EXHIBIT 2-23:
RIO ALGOM URANIUM OPERATIONS, 1981-1983

	1983	1982	1981
Million $			
Revenues	297.6	281.7	281.9
Operating Income	76.1	60.3	69.2
Capital Expenditures	87.8	13.7	17.3
Assets	752.9	427.8	372.1
Depreciation, Amortization	29.9	28.1	30.7
Tons U_3O_8			
Total Production	3,400	3,550	3,900
Canadian Production	3,233	NA	NA
U.S. Production	167	NA	NA

Source: AR 83b

EXHIBIT 2-24:

PHELPS DODGE ENERGY OPERATIONS, 1981-1984[a]

	1984[b]	1983	1982	1981
Million $				
Revenues	na	25.4	34.8	89.5
Operating Income	na	(10.8)	(17.3)	10.3
Capital Expenditures	na	1.6	5.3	9.8
Assets	na	156.5	154.2	168.8
Depreciation, Amortization	na	5.3	3.4	7.7
Physical Quantities				
U_3O_8 Production (Tons)	na	303	250	631
Ore Reserves (1000 Tons)	na	15,700	15,400	15,400

na = not available

[a] Phelps-Dodge uranium operations are conducted through its subsidiary Western Nuclear. Uranium operations are included in the "Energy" business segment in the annual reports. Also in this segment is a gas and oil exploration subsidiary, but the annual report states that the energy segment consists principally of uranium operations.

[b] The company wrote off its entire investment in Energy operations in the fourth quarter of 1984.

Sources: AR 83c, AR 84d.

Rocky Mountain Energy

Rocky Mountain Energy, a subsidiary of Union Pacific Corporation, owns a mine and mill complex in Powder River Basin, Wyoming. In 1984, the company shipped 271 tons of uranium oxide to Southern California Edison and San Diego Gas and Electric. Because Union Pacific expects new opportunities for producers of U_3O_8, uranium exploration operations have continued, primarily in an area of northern Arizona where high grade deposits are known to exist (AR 84e). The 2000 ton per day mill was inactive in 1985, however, and decommissioning is anticipated (PEI 85a).

Financial statistics for Union Pacific's mining operations, which include large coal and soda ash activities in addition to uranium, are provided in Exhibit 2-25a. Information on reserves and production is presented in Exhibit 2-25b.

Other Producers

The above companies were the only producers publishing detailed information on uranium operations. Limited information pertaining to other mill operators obtained, either through annual reports or industry sources, follows:

- The Cotter Corporation, a subsidiary of Commonwealth Edison Co., owns three underground mines and a 1200 ton per day mill at Canon City, Colorado. The mill and two of the mines have been on standby since January 1985. As of December 31, 1984, Commonwealth Edison reported assets of $212,135,000 in uranium related property, equipment, and activities (AR 84f).

- Union Carbide owns several uranium mines and three uranium mills in Colorado, Wyoming, and Utah. Maximum rated capacities of the mills are 1300, 1400, and 2000 tons per day. The company reported in its most recent annual report that its uranium mines and mills operated below capacity in 1984, although at higher rates than in 1983 (AR 84g). As of September 1985, all three mills were on standby, but the largest mill, at White Mesa, Utah, was reopened in October to meet a contract (PEI 85a).

- Kennecott, a subsidiary of Standard Oil of Ohio, owns a 1650 ton per day mill at Cebolleta, New Mexico. The mill has been inactive since the early 1980's (DOE 85a).

EXHIBIT 2-25(a): UNION PACIFIC MINING OPERATIONS: FINANCIAL INFORMATION, 1981-1984

Million $	1984	1983	1982	1981
Revenues	168.0	189.0	165.4	179.1
Operating Income	63.0	67.0	48.2	48.6
Capital Expenditures	1.0	18.0	11.0	12.0
Assets	288.0	303.0	322.8	326.6
Depreciation, Amortization	5.0	7.0	8.6	3.0

EXHIBIT 2-25(b): UNION PACIFIC URANIUM RESERVES AND PRODUCTION

(1000 pounds of U_3O_8)

	1984[1]	1983	1982	1981	1980
Reserves					
Undeveloped	1,553	2,846	2,846	2,846	2,852
Interest in joint venture	2,897	4,524	5,698	6,019	5,506
Leased Properties	648	648	943	943	626
Production	233	287	395	525	360

[1]1984 reserves were adjusted downward by 34 percent to reflect future market prospects.

Sources: AR 84e, AR 83d

- United Nuclear Corporation, a subsidiary of UNC Resources, Inc., has historically been a major producer of uranium. However, since 1983 all the company's mines have been on standby due to depressed market conditions, as has its 4000 ton per day mill at Gallup, New Mexico. The company has been filling its contract commitments with uranium purchased from outside sources. Plans for 1985 call for complete elimination of uranium operations (AR 84h).

- Anaconda, a subsidiary of Atlantic Richfield Co., owns a 6000 ton per day uranium mill at Grants, New Mexico. The mill has been on standby since 1982 (DOE 85a).

- Chevron Chemical Company, a subsidiary of Chevron Corporation, owns a 2600 ton per day mill at Hobson, Texas. The mill was active thru 1984 but in 1985 began only grinding alkaline rock to neutralize its tailings pool (PEI 85a). The company expects that, although prices are now depressed, uranium will be profitable in the future. Plans are underway to test commercial production of uranium at Mt. Taylor, New Mexico in 1985 (AR 84i).

- Atlas Corporation owns four underground uranium mines and a 1400 ton per day mill located in Moab, Utah. The mill operated at least part of the year through 1984, but as of June 1985 was inactive (DOE 85a, JFA 85b).

- Dawn Mining is a joint operation of Newmont Mining Corporation of New York and Midnight Mining Company of Spokane, Washington. The company owns a 600 ton per day mill near Ford, Washington. The mill has been inactive since 1982 (DOE 85a, JFA 85b).

- Pathfinder Mines owns five uranium mines and two uranium mills in Wyoming. Both mills operated through 1984. As of October 1985, the 2500 ton per day mill at Gas Hills was on standby, but the 1800 ton per day facility at Shirley Basin was active (PEI 85a, JFA 85b).

- Minerals Exploration, a subsidiary of Union Oil, owns a 3000 ton per day mill near Red Desert, Wyoming. The mill has been on standby since 1983 (DOE 85a, JFA 85b).

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WY 80,81, and 84 Wyoming State Inspector of Mines, 1980, 1981, and 1984 annual reports.

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CHAPTER 3:

PROFILE OF TAILINGS IMPOUNDMENTS AT LICENSED URANIUM MILLS

This chapter provides a profile of the status of existing tailings impoundments. The list includes only those impoundments at existing licensed uranium mills. Impoundments at mills which are currently decommissioned are not included. The information presented in this chapter was developed as part of the Background Information Document (EPA 86)prepared for this final rulemaking by PEI Associates, Inc. Data was collected by contacting mill owners, through site visits, and aerial photographs. Information is provided on forty-three existing impoundments of which thirty-eight are actual tailings impoundments and five represent evaporation ponds.

Exhibit 3-1 provides summary information on the characteristics and areas of the existing impoundments. The first column of the exhibit provides information on the type of pile. A type one impoundment is one enclosed by dams and dikes (embankments) constructed with sand tailings. A type two impoundment is one constructed using earthen embankments. Type three impoundments are those constructed below grade. Most existing tailings piles are of type two. The use of sand tailings for embankments (type one) has been discouraged for some time and is no longer permitted. Only five below-grade piles (at three sites) have been constructed as of this date.

The second column of Exhibit 3-1 provides the status of existing impoundments. Piles of status "C" are those that are at capacity. Status "S" piles are on standby and status "A" piles are currently active.

The areas of the existing impoundments are also given in Exhibit 3-1. Areas are given in total and for ponded, wet and dry areas. The areas are important because only dry areas are assumed to have substantial emissions of radon-222. The final column of Exhibit 3-1 provides the average radium-226 content of the tailings. These data are also used in the calculation of radon-222 emissions.

Exhibit 3-2 provides the emissions of radon-222 in kCi/year given current water conditions. Current emissions are calculated using a flux factor of 1 pCi radon-222 per m^2 per second for 1 pCi radium-226 per gram concentration for dry tailings areas, and a

EXHIBIT 3-1

SUMMARY OF URANIUM MILL TAILINGS PILES

Site/ Pile	a/ Type of Pile	b/ Status	Size (acres) Total	Ponded	Wet	Dry	Average Ra-226 (pCi/g)
Colorado							
Cotter Corp.							
Primary	2	S	84	77	3	4	780
Secondary	2	C	31	1	1	30	780
Umetco							
Pile 1 & 2	1	C	66	0	4	62	480
Pile 3	1	C	32	0	3	29	480
Sludge pile	1	C	20	0	1	19	480
Evap. pond	1	C	17	0	2	15	480
New Mexico							
Sohio							
L-Bar	1	S	128	28	55	45	500
United Nuclear							
Churchrock		S	148	7	76	65	290
Anaconda							
Bluewater 1	2	S	239	0	0	239	620
Bluewater 2	2	C	47	0	0	47	620
Bluewater 3	2	C	24	0	0	24	620
Evap. ponds	2	S	162	97	17	48	620
Kerr-McGee							
Quivira 1	1	S	269	14	64	191	620
Quivira 2a	1	S	105	10	35	60	620
Quivira 2b	1	S	28	0	3	25	620
Quivira 2c	1	S	30	0	4	26	620
Evap. ponds	2	S	372	268	10	95	620
Homestake							
Homestake 1	1	S	205	63	33	109	385
Homestake 2	2	C	44	4	0	36	385
Texas							
Chevron							
Panna Maria	2	S	124	68	20	36	196
Utah							
Umetco							
White Mesa	3	S	48	7	7	34	350
White Mesa	3	S	61	10	6	45	350
White Mesa	3	S	53	39	0	14	350

EXHIBIT 3-1 (Cont.)

SUMMARY OF URANIUM MILL TAILINGS PILES

Site/ Pile	a/ Type of Pile	b/ Status	Size (acres) Total	Ponded	Wet	Dry	Average Ra-226 (pCi/g)
Rio Algom							
Rio 1	2	A	44	4	2	38	560
Rio 2	2	A	32	12	5	15	560
Atlas							
Moab	1	S	147	54	4	90	540
Plateau Res							
Shootering	2	S	7	2	1	4	280
Washington							
Dawn Mining							
Ford 1,2,3	2	C	95	0	0	95	240
Ford 4	3	S	28	17	0	11	240
Western Nuclear							
Sherwood	2	S	94	18	7	70	200
Evap. pond	2	S	16	16	0	0	200
Wyoming							
Pathfinder							
Gas Hills 1	2	S	124	2	3	119	420
Gas Hills 2	2	C	54	2	12	40	420
Gas Hills 3	2	S	22	19	2	2	420
Gas Hills 4	2	S	89	73	4	11	420
Western Nuclear							
Split Rock	2	S	156	94	19	43	430
Umetco							
E. Gas Hills	2	C	151	0	0	151	310
A-9 Pit	3	S	25	2	9	14	310
Leach pad	2	S	22	0	0	22	310
Evap ponds	2	S	20	20	0	0	310
Rocky Mountain Energy							
Bear Creek	2	S	121	45	23	53	420
Pathfinder							
Shirley Basin	2	A	261	179	22	60	540
Minerals Exp.							
Sweetwater	2	S	37	30	0	7	280
TOTALS			3882	1282	457	2143	

a/Type of impoundment: 1 = dam constructed of coarse tailings; 2 = earthen dam; 3 = below grade.

b/Status of impoundment: A = active; S = standby (will be used when operations resume); C = filled to capacity (will not be used again).

EXHIBIT 3-2:

SUMMARY OF RADON-222 EMISSIONS FROM EXISTING TAILINGS IMPOUNDMENTS UNDER CURRENT CONDITIONS

State	Company Name	Pile Name	kCi/y
Colorado	Cotter Corp	Primary	0.4
		Secondary	3.0
	Umetco	Pile 1&2	3.8
		Pile 3	1.8
		Sludge Pile	1.2
		Evap. Pond	0.9
New Mexico	Sohio	L-Bar	2.9
	United Nuclear	Churchrock	2.4
	Anaconda	Bluewater 1	18.9
		Bluewater 2	3.7
		Bluewater 3	1.9
		Evap. Ponds	3.8
	Kerr-McGee	Quivira 1	15.1
		Quivira 2a	4.7
		Quivira 2b	2.0
		Quivira 2c	2.1
		Evap. Ponds	7.5
	Homestake	Homestake 1	5.4
		Homestake 2	1.8
Texas	Chevron	Panna Maria	0.9
Utah	Umetco	White Mesa	1.5
		White Mesa	2.0
		White Mesa	0.6
	Rio Algom	Rio 1	2.7
		Rio 2	1.1
	Atlas	Moab	6.2
	Plateau Res.	Shootaring	0.1
Washington	Dawn Mining	Ford 1,2,3	2.9
		Ford 4	0.3
	Western Nuclear	Sherwood	1.8
		Evap. Pond	0.0
Wyoming	Pathfinder	Gas Hills 1	6.4
		Gas Hills 2	2.1
		Gas Hills 3	0.1
		Gas Hills 4	0.6
	Western Nuclear	Split Rock	2.4
	Umetco	E. Gas Hills	6.0
		A-9 Pit	0.6
		Leach Pad	0.9
		Evap. Ponds	0.0
	Rock Mt. Energy	Bear Creek	2.8
	Pathfinder	Shirley Basin	4.1
	Minerals Exp.	Sweetwater	0.2
U.S. TOTAL			130

flux of zero for ponded and wet areas. Emissions at existing impoundments range from zero to 18.9 kCi/year.

Exhibit 3-3 summarizes the estimated fatal cancers which will result from existing tailings impoundments under current water-cover conditions. The estimated fatal cancers are calculated using emissions estimates discussed above and the EPA-AIRDOS computer code which uses a dispersion model and local site-specific population estimates. A factor of 1.2×10^{-2} fatal cancers per kCi per year released is used to generate national health effects estimates. This estimate was derived from Table 3-1 and the national risk on page 6-15 of EPA document number 520/1-83-008-1. Estimated committed total cancers from existing tailings impoundments range from zero to 0.4 fatalities per year.

EXHIBIT 3-3:

SUMMARY OF ESTIMATED ANNUAL FATAL CANCERS FROM EXISTING TAILINGS IMPOUNDMENTS UNDER CURRENT CONDITIONS

State	Company Name	Pile Name	Committed Cancers Per Year
Colorado	Cotter Corp	Primary	.01
		Secondary	.09
	Umetco	Pile 1&2	.07
		Pile 3	.03
		Sludge Pile	.02
		Evap. Pond	.02
New Mexico	Sohio	L-Bar	.08
	United Nuclear	Churchrock	.05
	Anaconda	Bluewater 1	.4
		Bluewater 2	.09
		Bluewater 3	.04
		Evap. Ponds	.09
	Kerr-McGee	Quivira 1	.3
		Quivira 2a	.08
		Quivira 2b	.04
		Quivira 2c	.04
		Evap. Ponds	.1
	Homestake	Homestake 1	.1
		Homestake 2	.05
Texas	Chevron	Panna Maria	.04
Utah	Umetco	White Mesa	.02
		White Mesa	.03
		White Mesa	.008
	Rio Algom	Rio 1	.04
		Rio 2	.02
	Atlas	Moab	.1
	Plateau Res.	Shootaring	.001
Washington	Dawn Mining	Ford 1,2,3	.03
		Ford 4	.004
	Western Nuclear	Sherwood	.03
		Evap. Pond	.0
Wyoming	Pathfinder	Gas Hills 1	.08
		Gas Hills 2	.03
		Gas Hills 3	.001
		Gas Hills 4	.007
	Western Nuclear	Split Rock	.03
	Umetco	E. Gas Hills	.07
		A-9 Pit	.007
		Leach Pad	.01
		Evap. Ponds	.0
	Rock Mt. Energy	Bear Creek	.04
	Pathfinder	Shirley Basin	.05
	Minerals Exp.	Sweetwater	.002
U.S. TOTAL			2.4

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CHAPTER 4

FUTURE URANIUM MILLING INDUSTRY ACTIVITY

The initial chapters of this report have described how the uranium milling industry has developed over the past two decades, and where it stands today. The presentation chronicles the large swings in production levels and capital investment and discusses the volatile nature of the industry. In order to measure the potential environmental damage that would be caused by this industry in the absence of regulation and to estimate the added cost of new regulations affecting this industry, it is necessary to develop a profile of how the industry will develop in the future.

Any projection of future production levels and work practices for the uranium milling industry are highly uncertain due to the political nature of the product, defense implications of domestic uranium production, public sensitivity to nuclear related activities, abundant low-cost foreign supplies of uranium and the general difficulty of developing forecasts for a long enough term to capture the full dynamics of this industry as well as the related mill waste disposal process. Despite these and other uncertainties, the future profile of this industry must be constructed in order to understand the potential impacts of various regulatory alternatives.

In this chapter a baseline or reference case for the future of this industry is developed. In order to establish a long enough time frame to capture mill and tailings impoundment life cycles, the reference case includes all final cover costs and life cycle emissions from existing impoundments and from those future impoundments that begin operation over the next 100 years. Assumptions are developed on the future activity of existing mills, the design and operating characteristics of newly constructed mills, the expected life cycle of all mills and tailings impoundments, the emissions and fatal lung cancers from existing and future mill sites, and the cost of achieving final stabilization of these impoundments.

The following sections present the elements of this baseline. In the subsequent analysis of alternative regulatory activities (Chapter 6), each of the key assumptions made in order to develop this baseline are tested to determine their importance in the analysis of regulatory alternatives.

4.1 PROJECTIONS OF DOMESTIC URANIUM PRODUCTION

In this section, two sets of projections are developed of total domestic uranium production and of domestic production from conventional sources for use in subsequent analyses. The projections are developed for the 101-year time period 1985-2085 and consist of two components: near-term projections, through the year 2000; and long-term scenarios, covering 2001-2085. The long-term components are referred to as "scenarios" to emphasize the relatively conjectural nature of any set of projections for such an extended timeframe. These scenarios presume that, during the next 100 years, there is no technological breakthrough which permits either a cessation in the construction of new uranium-fueled nuclear power plants or a vast reduction in the uranium requirements for nuclear power (as would result from the development of a breeder reactor).

The two sets of projections consist of one set of moderately low projections and one set of moderately high projections. For the purposes of subsequent analyses, these two sets will be referred to as the "reference" case and the "alternate" case, respectively, though these names are not intended to imply any difference in the perceived reasonableness of the two sets of projections.

4.1.1 Near-Term Projections

Total domestic production of U_3O_8 and domestic production from conventional uranium sources for 1980-1984 are shown in tabular form in Exhibit 4-1 along with reference-case and alternate-case projections of these two categories of production for the period 1985-2000. The projections of total domestic production during 1990-2000 are taken from recently published DOE low-demand and middle-demand projections for domestic production under free market conditions (DOE 85c, pp. 147-148). Projected 1985 production shown in the exhibit has been adjusted from the DOE projections, developed in early 1985, to reflect the latest available information on mill operations.[1] This

[1] Only two mills (Rio Algom and Pathfinder/Shirley Basin) have operated the entire year. Three mills (Chevron, Cotter and Petrotomics) were operating at the beginning of 1985, but closed during the first half of the year, while one mill (UMETCO/White Mesa) reopened in October.

EXHIBIT 4-1:

ANNUAL DOMESTIC PRODUCTION OF U_3O_8, 1980-2000

(Short Tons)

	Reference Case		Alternate Case	
	Total	Conventional	Total	Conventional
1980	21,852	18,600	21,852	18,600
1981	19,237	15,100	19,237	15,100
1982	13,414	10,119	13,414	10,119
1983	10,579	7,474	10,579	7,474
1984	7,441	4,618	7,441	4,618
1985	4,350	1,800	4,350	1,800
1986	4,350	1,800	4,450	1,900
1987	4,300	1,850	4,550	2,000
1988	4,300	1,850	4,750	2,200
1989	4,350	1,900	4,950	2,400
1990	4,350	1,900	5,150	2,600
1991	4,350	1,900	5,300	2,700
1992	4,600	2,100	5,350	2,750
1993	4,950	2,450	5,050	2,550
1994	5,250	2,650	5,100	2,600
1995	5,450	2,800	5,750	3,100
1996	5,750	3,000	6,650	3,800
1997	6,050	3,200	7,550	4,500
1998	6,300	3,400	8,150	4,950
1999	6,450	3,500	8,450	5,150
2000	6,550	3,600	8,600	5,250

Sources: 1980-1984 and total production in 1990-2000: DOE 85c, pp. 147-148;
1985-1989: see text.

information indicates that mill output in 1985 is likely to be only about 1800 short tons (down from 4618 tons in 1984). To be consistent with this sharp reduction in conventional production, we estimate total domestic production in 1985 to be 4350 tons (800 tons below the DOE figure developed earlier this year). Our reference-case projections for 1986-1989 were obtained by assuming a slight dip in production to 4300 tons (in 1987 and 1988) followed by a return to 4350 tons, which is DOE's low-demand projection for 1990. Our alternate-case projections for 1986-1989 were obtained by assuming a gradual increase from the 1985 level to the 1990 value (5150 tons) obtained from DOE's middle-demand projections.

Even before our downward adjustments for the 1985-1989 period, DOE's projections of domestic uranium production were 30 to 50 percent lower than their previous projections (DOE 84b, pp. 157-158). These substantial reductions in projected domestic production are due both to a reduction in projected domestic U_3O_8 requirements and to an increase in the portion of these requirements expected to be met through imports. The reduction in domestic requirements is due to eight reactor cancellations in 1984 and early 1985, an assumed gradual improvement in the enrichment tails assay (from 0.26 percent in 1985 to 0.20 percent in 2000), and an assumed gradual increase in fuel burnup levels (to 30 percent above 1983 levels). As a result of imports and drawdowns from currently high inventory levels, domestic production is projected to provide less than 40 percent of annual U_3O_8 requirements throughout the 1985-2000 period and less than 30 percent during much of this period.

Annual domestic U_3O_8 production peaked at 21,852 tons (after milling)[1] in 1980 and then declined by 66 percent, to 7441 tons in 1984. This decline is projected to continue, to 4350 tons in 1985 and, in our reference case, to 4300 tons in 1987 and 1988. Annual domestic U_3O_8 production from conventional mining soures (i.e., from milling of ore obtained from underground or open-pit mining) has fallen even more steeply than overall production: by 75 percent, from about 18,600 tons in 1980 to 4618 tons in 1984. As a result, the percentage of U_3O_8 obtained from conventional sources has declined from 85 percent in 1980 to 62 percent in 1984.

The reason for the relatively steeper decline in production from conventional sources is that nonconventional U_3O_8 producers tend to have lower marginal costs of production

[1] All U_3O_8 production data presented in this chapter is after milling and excludes U_3O_8 which is not recovered from the ores in milling. In recent years, the milling recovery rate has been between 95 and 97 percent.

than conventional producers, and so production from nonconventional sources tends to be less affected by the recent decline in uranium prices. Indeed, production from the largest category of nonconventional sources, byproduct production, is virtually independent of uranium prices (and has actually risen from about 1300 tons in 1981 to about 1650 tons in 1984). The primary source of byproduct U_3O_8 is wet-process production of phosphoric acid; other sources are copper waste dumps (a source which can be affected by uranium prices) and beryllium ores. The second significant nonconventional source is in situ leaching, which yielded about 2100 tons of U_3O_8 in 1981 and about 1000 tons in 1984. Other less important sources include mine water and heap leaching; 255 tons of U_3O_8 were obtained from these sources in 1984.

The projections of domestic U_3O_8 production from conventional sources shown in Exhibit 4-1 were derived by JFA from the projections of total production by assuming that conventional sources would continue to be more affected by changes in the market than unconventional sources. Accordingly, conventional production is projected to decline from 4618 tons in 1984 (62 percent of total production) to 1800 tons in 1985 (41 percent of total production) before beginning to increase gradually in both total volume and percentage of production.

The low-demand and middle-demand DOE projections of domestic U_3O_8 production through the year 2000 are the only recently published projections of domestic uranium production.[1] These projections are based on a unit-by-unit review of nuclear power plants that are now operating or under construction. Under DOE's middle-demand case, nuclear generating capacity is expected to increase from 71 GWe in 1984 to 117 GWe in 1993, and then to decline slightly to 116 GWe in the year 2000. Under the low-demand case, DOE estimates that about 10 GWe of new capacity currently on order will be canceled, resulting in a peak capacity of 107.5 GWe in 1992 followed by a slight decline to 106.4 GWe in the year 2000. Both sets of projections assume no reactors which have not already been ordered will come on-line by the year 2000, and the low-demand uranium production projections further assume no new orders through 2010.

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[1] Short-term and long-term projections of United States uranium production capability have also been published by the Organisation for Economic Co-operation and Development in 1983 (OECD 83, pp. 316 and 318). These projections show production capability rising from 10,300 metric tonnes in 1984 to 14,000-18,700 tonnes in 1995 and 9400-20,000 tonnes in 2005. Presuming that production during the short-term would be limited by capability and not by demand (as actually appears to be the case), OECD projects that resource depletion will result in a substantial decline in production capability after 2005, falling to 2500-3700 tonnes in 2025.

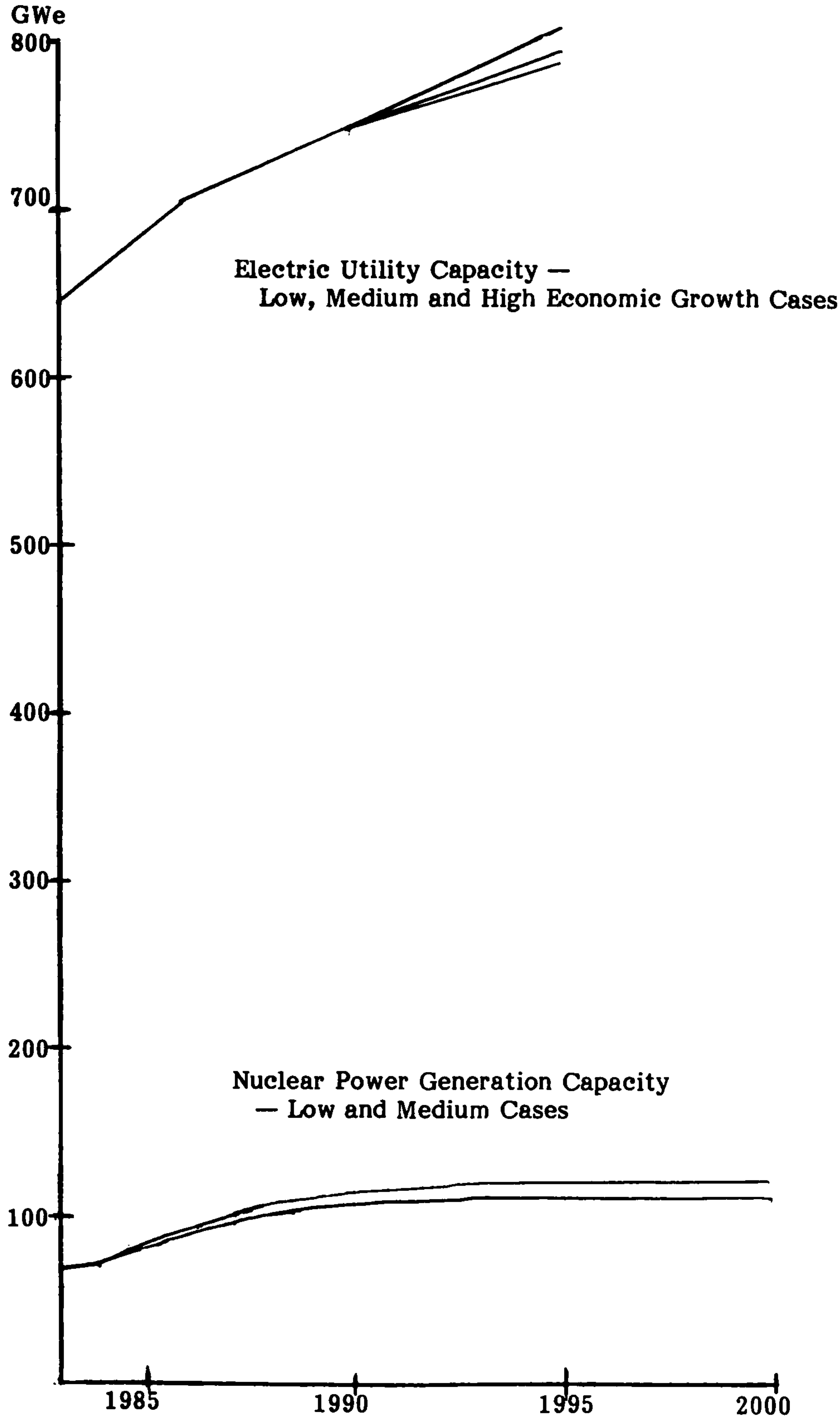
The two sets of projections of nuclear generating capacity underlying DOE's uranium production are shown graphically in Exhibit 4-2, along with three sets of DOE projections of total generating capacity through 1995 (which is as far as currently available DOE projections of total generating capacity go). DOE also has developed a high set of projections of nuclear generating capacity (but not of uranium production); the high projections differ only slightly from the middle projections and are not shown in the exhibit. The three sets of total generating capacity projections shown in Exhibit 4-2 represent three of the five sets of such projections developed by DOE; the remaining projections, which presume either higher or lower real increases in fuel prices in the post-1990 period, have been omitted from the exhibit to avoid clutter. All DOE projections of total generating capacity incorporate the middle-case projections of nuclear generating capacity.

The Exhibit 4-1 historic data and reference-case projections for total domestic uranium production and domestic production from conventional sources are shown graphically in Exhibit 4-3. The latter exhibit also shows historic data and projections of total enrichment feed deliveries, net change in U_3O_8 inventories, and net imports. With the exception of 1985-1989 net imports, these last three series are taken from DOE's low-demand projections (DOE 85c, pp. 148, 150 and 152); the level of net imports shown in the exhibit for 1985-1989 are slightly higher than DOE's low-demand projections because of our downward adjustment of total domestic production.

Exhibit 4-4 shows plots of corresponding values for our alternate-case projections of domestic uranium production and for projections of total enrichment feed deliveries, net change in U_3O_8 inventories, and net imports obtained from DOE's middle-demand projections of these quantities (DOE 85c, pp. 147, 149 and 151) in the same fashion as the plots in Exhibit 4-3. The middle-demand projections of total enrichment feed deliveries for 1985-1994 were obtained by DOE directly from utility estimates of feed deliveries. DOE also developed their own projections of enrichment feed deliveries for 1985-2000, but used these projections only for developing production estimates for 1995-2000. The DOE projections for 1985-1994 show less year-to-year fluctuation and are generally somewhat lower than the utility estimates (which are the ones shown in Exhibit 4-4).

EXHIBIT 4-2:

PROJECTED ELECTRICITY-GENERATION CAPACITY

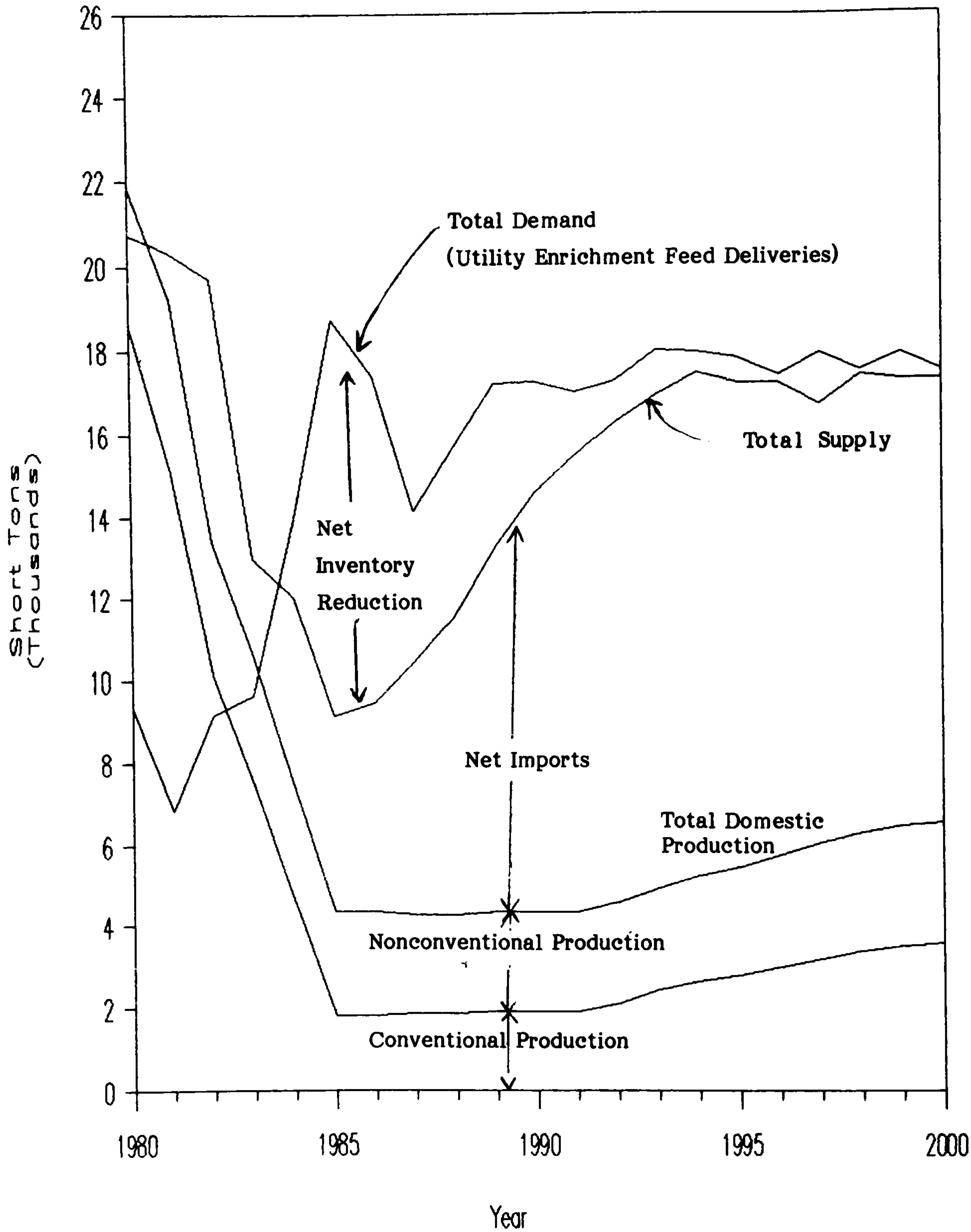


Sources: DOE 85a, pp. 215, 235 and 255; and DOE 85c, pp. 28-29.

EXHIBIT 4-3:

SOURCES OF URANIUM SUPPLY:

1980-1984 AND REFERENCE CASE PROJECTIONS THROUGH THE YEAR 2000

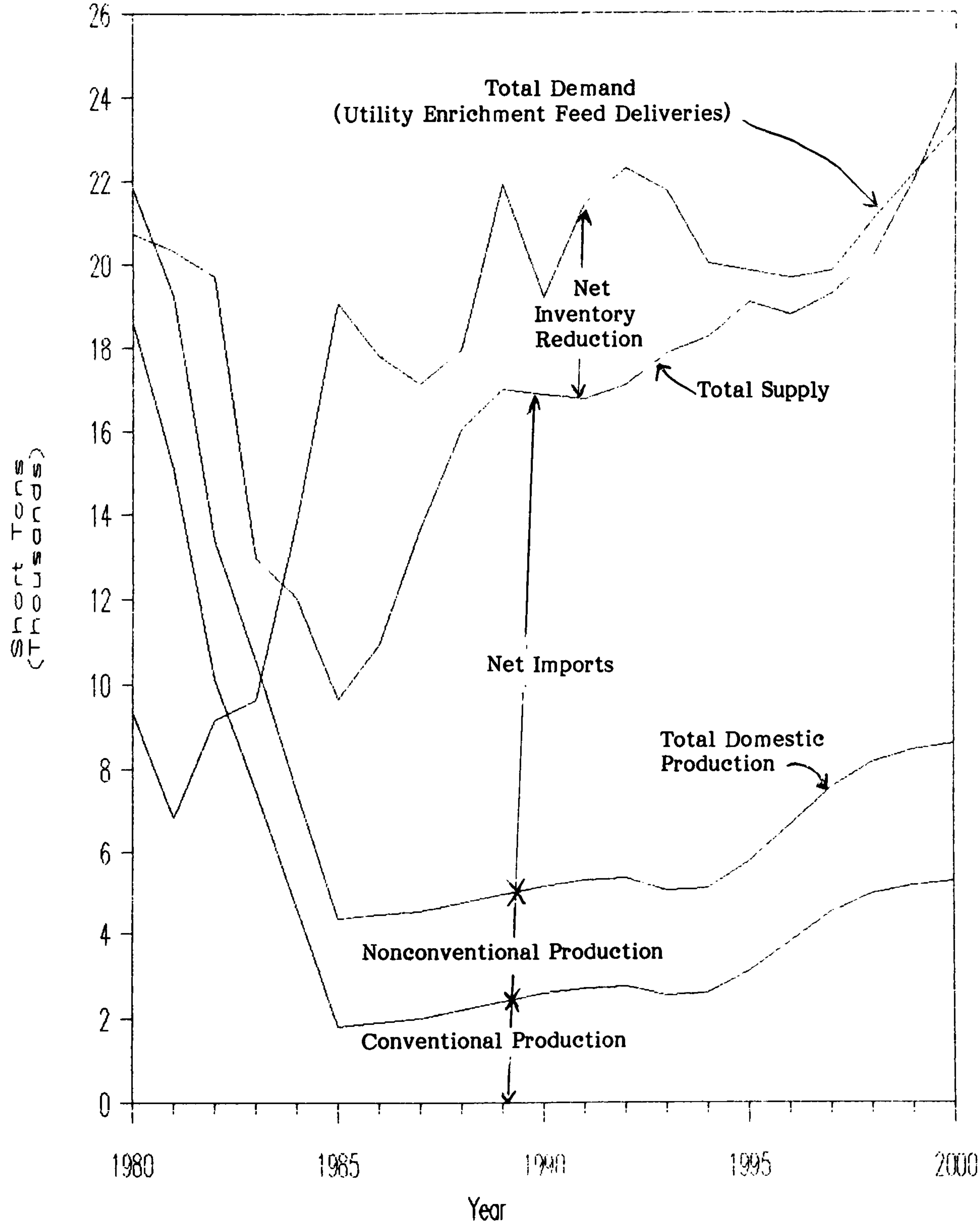


Sources: Exhibit 3.1 and DOE 85c, pp. 148, 150 and 152.

EXHIBIT 4-4:

SOURCES OF URANIUM SUPPLY:

1980-1984 AND ALTERNATIVE-CASE PROJECTIONS THROUGH THE YEAR 2000



Sources: Exhibit 3.1 and DOE 85c. [illegible] 151.

The increase in enrichment feed deliveries shown in Exhibit 4-4 for the 1997-2000 period reflect DOE's middle-demand case assumption that nuclear generating capacity will begin to increase significantly in 2001. Although this assumption may not be appropriate, it does not appear to have a significant effect on DOE's projections of domestic U_3O_8 production during this time period, and so DOE's projections were accepted for this time period without modification.

4.1.2 Long-Term Scenarios

In this section, long-term scenarios of total domestic production of U_3O_8 and of domestic production from conventional uranium sources are presented and discussed. The discussion includes a comparison of total domestic uranium production under the two scenarios during 1985-2085 to estimated domestic resources and a discussion of the relationship of projected domestic uranium production in 2085 to the implications for electricity generated in that year from this source and from other sources.

The Scenarios

Reference-case and alternate-case scenarios of total domestic production of U_3O_8 and of domestic production from conventional uranium sources for 2000-2085 are shown in tabular form in Exhibit 4-5. The two scenarios of total production were obtained by assuming annual growth rates of 1.4 percent and 2.8 percent, respectively, during the first twenty years of this period and then a gradual reduction of four percent per year in the growth rates for the remainder of the period. It can be seen from the exhibit that, by 2085, annual uranium production under both scenarios will have nearly leveled off. The projected production levels of 11,961 and 28,499 tons in 2085 under the two scenarios may be compared to actual production of 21,900 tons in 1980, when the historic peak in production was set.

The annual growth rates of 1.4 and 2.8 percent in total domestic uranium production used during 2000-2020 are identical to the average annual growth rates obtained during this period in DOE's 1984 low-case and middle-case projections of installed nuclear capacity (DOE 84a, p. 19) and lower than the corresponding 1.5 and 3.9 percent growth rates

EXHIBIT 4-5:

POST-2000 PROJECTIONS OF ANNUAL DOMESTIC PRODUCTION OF U_3O_8

(Short Tons)

	Reference Case		Alternate Case	
	Total	Conventional	Total	Conventional
2000	6,550	3,600	8,600	5,250
2005	7,022	3,954	9,873	6,205
2010	7,527	4,333	11,335	7,301
2015	8,069	4,739	13,014	8,560
2020	8,650	5,175	14,940	10,005
2025	9,223	5,605	16,974	11,530
2030	9,720	6,052	18,839	13,209
2035	10,144	6,434	20,514	14,717
2040	10,505	6,758	21,992	16,047
2045	10,808	7,031	23,278	17,204
2050	11,062	7,260	24,382	18,198
2055	11,274	7,451	25,322	19,044
2060	11,450	7,609	26,116	19,759
2065	11,595	7,739	26,782	20,358
2070	11,715	7,847	27,338	20,859
2075	11,813	7,936	27,800	21,274
2080	11,894	8,009	28,183	21,619
2085	11,961	8,069	28,499	21,903

obtained in the 1985 DOE projections[1] (DOE 85b, p.22). It should be observed, however, that our growth rates represent growth in domestic production of uranium and not installed nuclear capacity, and so our two scenarios do not necessarily correspond to 1.4 and 2.8 percent growth rates in nuclear capacity. Factors which might cause nuclear capacity to grow at a different rate than domestic uranium production include: a change in the percentage of uranium imported (from the 61 percent and 67 percent levels projected in the year 2000); improved reactor efficiency or enrichment-plant efficiency; the use of higher fuel burnup levels; and spent-fuel reprocessing. Considering these factors, as well as constraints on resource availability (discussed in the following subsection), it is our belief that the 1.4 and 2.8 percent rates of increase in domestic uranium production are appropriate for use in a moderately low scenario and a moderately high scenario, respectively.

In addition to the DOE low-case and middle-case projections of installed nuclear capacity discussed above, DOE has developed projections for a high case and a no-new-orders case. DOE's 1984 and 1985 high-case projections have average annual growth rates during 2000-2020 of 5.2 and 5.9 percent, respectively. During the same period, as

[1] The higher growth rates obtained in the 1985 DOE projections appear to result from an inconsistent set of parameter modifications made by DOE between the 1984 and 1985 runs of the World Integrated Nuclear Evaluation System (WINES). This system (DOE 85b, pp. 90-95) requires several user-specified parameter values, including the growth rate in real aggregate energy prices and the rate at which the nuclear share of electrical generation approaches in exogenously specified asymptote.

Continued softness in the price of fossil fuels makes it likely that energy price increases during the 2000-2020 time period will be lower than previously expected, and that the eventual shift to nuclear energy will be slower than previously expected. Accordingly, between the 1984 and 1985 WINES runs, DOE reduced the values assigned to both the real energy-price growth rate and the rate at which the nuclear share of electrical generation approaches its asymptote. The first of these changes results in a substantial increase in projected energy consumption, electricity consumption, and nuclear power generated; while the second change tends to slow or, if large enough, to reverse the increase in nuclear power generated (at least during 2000-2020). It appears likely that if real growth in fossil-fuel prices remains moderate, as now forecast, the rate at which the nuclear share of electrical generation increases will be substantially lower than assumed by DOE in the 1985 WINES run. We believe that, if a better representation of the rate at which the nuclear share of electrical generation grows during 2000-2020 had been used in the 1985 WINES run, the system would have produced nuclear generating capacity growth rates which are similar to or lower than those produced in the 1984 WINES runs.

a result of retirements, the no-new-orders case shows a sharp 60 GWe drop in installed nuclear capacity, starting from 109 GWe or 106 GWe (in the 1984 and 1985 reports, respectively) (DOE 84a, pp. 19 and 21; DOE 85b, pp. 22 and 24). DOE's projections of nuclear generation and installed nuclear capacity extend only as far as 2020. These projections and the OECD projections of uranium-production capability (OECD 83, discussed in an earlier footnote) are the only projections we have been able to find which extend beyond the year 2000 and which relate to uranium production or nuclear generation.

The projections of domestic production from conventional sources shown in Exhibit 4 5 were obtained by assuming that nonconventional sources would account for 25 percent of the increase in total production through the year 2025 and ten percent of the increase in subsequent years. By way of comparison, reduction in production from nonconventional sources accounted for about ten percent of the decline in production during 1980-1984. Increases in production from nonconventional sources are expected to be provided primarily from byproduct production and, as a result of continuing technological advances, from in situ leaching.

The primary source of byproduct production of U_3O_8 is from wet-process production of phosphoric acid. At a selling price of about $60 per pound (in 1985 dollars), potential U_3O_8 production from this source would currently be about 6000 tons (De 79); though, as a result of depletion of phosphate resources, this potential is expected to decline over time, to 5000 tons in 2000, 4600 tons in 2025, and presumably to lower values in subsequent years. Since prices are only expected to recover to about $50 per pound by the end of the century (DOE 85c, pp. 143-144), production from this source is likely to remain below maximum potential until well into the next century. The post-2025 decline assumed in the nonconventional-production growth rate reflects an expected gradual decline in phosphate-byproducts U_3O_8 production after the maximum potential production rate is attained.

Historic and projected total and conventional domestic uranium production for the 1980-2085 period, from Exhibits 4-1 and 4-5, are shown graphically in Exhibit 4-6. Exhibit 4-7 shows total production by five-year period and for the full 100-year period: 1986-2085.

EXHIBIT 4-6:

ANNUAL DOMESTIC PRODUCTION OF U_3O_8, 1980-2085

(Historic, 1980-1984; Projected, 1985-2085)

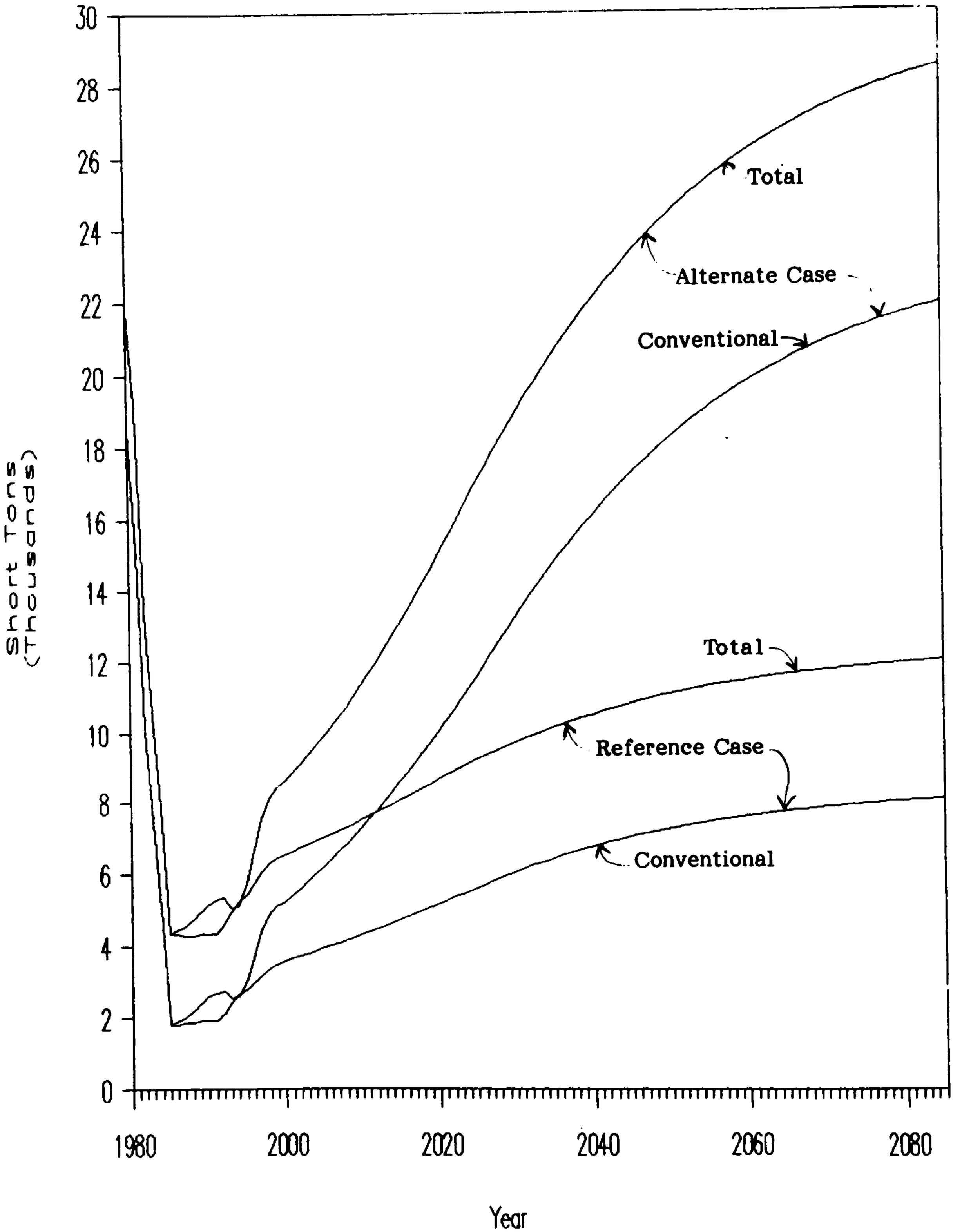


EXHIBIT 4-7:

PROJECTED TOTAL DOMESTIC PRODUCTION OF U_3O_8

(Short Tons)

	Reference Case		Alternate Case	
	Total	Conventional	Total	Conventional
1986 - 90	21,650	9,300	23,850	11,100
1991 - 95	24,600	11,900	26,550	13,700
1996 - 00	31,100	16,700	39,400	23,650
2001 - 05	34,151	19,051	46,750	29,062
2006 - 10	36,610	20,895	53,672	34,254
2011 - 15	39,245	22,872	61,618	40,214
2016 - 20	42,071	24,990	70,742	47,056
2021 - 25	45,001	27,188	80,862	54,646
2026 - 30	47,635	29,392	90,537	62,754
2031 - 35	49,899	31,430	99,300	70,640
2036 - 40	51,827	33,164	107,085	77,646
2041 - 45	53,455	34,630	113,893	83,774
2046 - 50	54,821	35,859	119,772	89,064
2051 - 55	55,962	36,886	124,794	93,585
2056 - 60	56,910	37,739	129,049	97,414
2061 - 65	57,695	38,445	132,628	100,635
2066 - 70	58,343	39,029	135,621	103,329
2071 - 75	58,877	39,509	138,113	105,571
2076 - 80	59,316	39,905	140,179	107,431
2081 - 85	59,677	40,229	141,887	108,968
1986-2085	938,846	589,113	1,876,300	1,354,491

Discussion

This section compares our scenarios for domestic production of U_3O_8, presented above, to total domestic uranium resources and discusses the relationship of the projections to total electricity generation.

Domestic Uranium Resources

The projections of domestic U_3O_8 production shown in Exhibit 4-7 (above) indicate that between 0.9 and 1.9 million tons of U_3O_8 will be produced domestically over the next 100 years. Over this time period, perhaps 200,000 to 300,000 tons may be obtained as a byproduct of mining of other minerals, with the remainder obtained from domestic mining of U_3O_8. A discussion of the potential for byproduct production of U_3O_8 is presented below, followed by a discussion of the extent of other domestic U_3O_8 resources.

Byproduct Production

The most significant domestic source of byproduct uranium is phosphate mining and processing. As indicated above, a 1979 DOE study (De 79) estimated that, by 1985, 6000 tons of U_3O_8 could be produced annually as a byproduct of wet-process production of phosphoric acid at a selling price of $40 per pound (1979 dollars), but that such production would decline gradually to 4600 tons by 2025. Presumably, potential production from this source will continue to decline after 2025. Since the average contract price for U_3O_8 is now only about $23 per pound (in current dollars) and is not expected to reach the required level until after the end of the century (DOE 85c, pp. 143-144), current production from this source is only about one-fourth of the indicated potential and is likely to remain below this potential for some time. However, over the full 100-year period, a substantial amount of U_3O_8 is likely to be obtained from this source, perhaps as much as 200,000 tons in the reference-case scenario and 300,000 tons in the alternate-case scenario. In addition, over this time frame, there may be some potential for a technological breakthrough which would make it economically feasible to obtain byproduct U_3O_8 from phosphate rock which is used for purposes other than the production of phosphoric acid.

Other potential sources of byproduct uranium are: copper waste dumps; the red mud obtained when alumina is removed from bauxite; and the beryllium ores of west-central Utah. A modest amount of U_3O_8 is currently being obtained from copper produced in Utah and Arizona, and DOE estimated in 1980 (DOE 80, p. 117) that 500 to 1000 tons of byproduct U_3O_8 could be obtained annually from copper ores. DOE also estimated at that time that a few hundred tons per year of byproduct U_3O_8 could be obtained from red mud and that 17 tons per year would be obtained from beryllium ores when an already installed circuit to recover uranium is put into operation.

Other Domestic Resources

The top half of Exhibit 4-8 shows DOE estimates of the total "endowment" of domestic U_3O_8 resources. The "endowment" is defined as all U_3O_8 contained in deposits containing at least 0.01 percent (100 ppm) of U_3O_8. The resource estimates shown in the top half of this exhibit are grouped by resource category and by "forward cost of recovery". The four resource categories used in the DOE publication which is the primary source (DOE 84c) for the information in the exhibit are those used by the International Atomic Energy Agency and the OECD Nuclear Energy Agency:

- Reasonably Assured Resources refers to uranium in known mineral deposits which could be recovered within given production cost ranges using currently proven technology (and corresponds to DOE's Reserves category).

- Estimated Additional Resources Category I refers to additional uranium expected to occur in extensions of well-explored deposits and in other deposits in which geological continuity has been established.

- Estimated Additional Resources Category II refers to additional uranium expected to occur in deposits believed to exist in well-defined geological trends or areas of mineralization with known deposits. (The two categories of Estimated Additional Resources, together, correspond to DOE's Probable Potential Resources category.)

- Speculative Resources refers to uranium which is thought to exist, mostly on the basis of indirect evidence and geological extrapolations (and corresponds to DOE's Possible Potential and Speculative Potential Resource categories).

EXHIBIT 4-8:
DOMESTIC URANIUM RESOURCES

Endowment[1]

(thousands of short tons of U_3O_8)

Forward Cost of Recovery	Resource Category: Reasonably Assured	Estimated Additional: Category I	Estimated Additional: Category II	Speculative	Total
$ 0 - $30/lb	180	42	630	540	1392
$31 - $60/lb.	390	72	440	460	1362
$51 - 100/lb.	315	100	605	620	1640
Total of Above	885	214	1675	1620	4394
Over $100/lb.					3056[3]
Total					7450[2]

Other Significant (but low-grade) Resources[2]

Marine Phosphorites	4 million tons
Chattanooga Shale	
Gassaway Member	5 million tons (55-70 ppm)
Dowelltown Member	no info.
Seawater	5 billion tons (3-4 ppb)

Sources

[1] DOE 84c, pp. 24-26, except as noted.

[2] DOE 80, pp. 116-118.

[3] Estimated from data in above sources. See text.

The "forward cost of recovery" of uranium resources represents estimates of most future costs of mining, processing and marketing U_3O_8, exclusive of return on capital. These estimates include the costs of transportation, environmental and waste management, construction of new operating units and maintenance of all operating units, future exploration and development costs, and appropriate indirect costs such as those for office overhead, taxes and royalties.

The top half of Exhibit 4-8 shows estimates of all U_3O_8 resources having a forward cost of recovery of no more than $100 per pound (1983 estimates) grouped by resource category plus one additional estimate of resources in the endowment having a cost of recovery of over $100 per pound. This latter estimate was derived by taking a set of 1980 estimates (DOE 80, pp. 33-113) of the total endowment in DOE's Probable, Possible and Speculative Potential Resource categories and subtracting Exhibit 4-8 estimates of the quantity of reserves in these three categories[1] having forward costs of recovery no greater than $100 per pound. This procedure corrects for changes in estimated forward cost of recovery between the 1980 and 1984 sources, but it does not correct for any additions or deletions which may have occurred to estimated resources in the three categories.

In addition to estimated U_3O_8 resources in the endowment, there are some large lower grade U_3O_8 resources. The most significant of these are Chattanooga Shale deposits, seawater, and the marine phosphorites from which (as discussed in the preceding subsection) U_3O_8 is currently being obtained as a byproduct of phosphoric acid production. It is estimated that the Gassaway Member of Chattanooga Shale is 55 to 70 ppm U_3O_8 and contains about 5 million tons of U_3O_8 (as well as larger amounts of vanadium, ammonia, sulfur and oil) (MSR 78); the Dowelltown Member lies beneath the Gassaway Member and is about the same thickness (fifteen feet) but is not further described in the DOE source (DOE 80, p. 116).

Seawater represents a huge, very low-grade source of uranium, averaging 3 to 4 parts per billion and containing perhaps five billion tons of U_3O_8. Using very optimistic assumptions, the cost of recovery using current technology has been estimated to be

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[1] As indicated above, DOE's Probable, Possible and Speculative Potential Resource categories correspond, as a group, to the two Estimated Additional Resource categories and the Speculative Resource category used in Exhibit 5.

\$1400 per pound of U_3O_8, though a Massachusetts Institute of Technology study suggests that improved technology could reduce the cost to \$300 per pound, and possibly to \$100 or less per pound (Ca 79 and Ro 79).

If, as suggested in the preceding subsection, about 200 to 300 thousand tons of U_3O_8 will be obtained over the next 100 years as a byproduct of other mining activities, the reference-case scenario previously presented in Exhibit 3.7 would require that about 700,000 tons of U_3O_8 be obtained from other domestic sources, and the alternate-case scenario would require that about 1.6 million tons be obtained from these sources. A relatively insignificant portion of this U_3O_8 could be obtained from existing tailings piles. (DOE has estimated that, as of January 1, 1980, about 9500 tons could be obtained from active and inactive tailings piles at a forward cost of \$100 per pound or less (DOE 80, p.119). Hence, the scenarios indicate that about 0.7 or 1.6 million tons of U_3O_8 will be obtained over the next 100 years from the domestic resources summarized in Exhibit 4-8.

Exhibit 4-8 (above) indicates that, excluding speculative resources, there are estimated to be 852,000 tons of U_3O_8 with a forward cost of recovery of no more than \$30 per pound, and 1.75 million tons with a forward cost of recovery of no more than \$60 per pound. Assuming an average U_3O_8 recovery rate of about 90 percent for all domestic mining over the next 100 years,[1] production of 700,000 tons would nearly deplete the resources with a forward cost of recovery of less than \$30 per pound; and production of 1.6 million tons might require the mining of at least some of the ore with a forward cost of recovery of over \$60 per pound (depending on the actual extent of our domestic resources and our ability to find them within the next 100 years).

Both scenarios would also result in a significant increase in the price of U_3O_8 from its present level of \$23 per pound to the \$35-\$80 per pound range (in 1983 dollars)[2] by 2085. These indicated real price increases are quite modest, since DOE is currently projecting contract prices of about \$40 per pound (1985 dollars) in the latter half of the next decade (DOE 85c, pp. 143-144).

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[1] The recovery rate in 1983 was actually 96.7 percent (DOE 84c, p. 20); however, it is assumed that this rate will decline with the declining grade of ore being mined.

[2] It should be noted that, since the "forward cost of recovery" does not include return on capital, the selling price of U_3O_8 will normally be higher than the forward cost of recovery.

Total Electricity Generation

Corresponding to each of the domestic U_3O_8 production scenarios for 2085 are a range of possible projections of total electricity consumption. One end of this range represents the situation in which nearly all electricity is obtained from conventional fission (i.e., from U_{235}) and uranium imports continue to be limited. In this situation, perhaps as much as one quarter of all electricity is derived from conventional fission of domestically produced uranium. The percentage of electricity may be lower than this as a result of greater use of imported uranium or as a result of greater use of electricity from alternative sources; e.g., coal or solar. (In developing our scenarios, we have assumed that there would be no technological breakthrough which permits either a cessation or a substantial reduction in the construction of new uranium-fueled nuclear power plants. Under various assumptions, the percentage of electricity derived from conventional fission of domestically produced uranium might be as low as two percent (or lower if any significant technological breakthrough occurs).

A range of projections of total electricity consumption in 2085 is presented in Exhibit 4-9. The projections correspond to the previously presented reference-case and alternate-case scenarios for domestic U_3O_8 production under the assumptions that 2, 5, 10 or 25 percent of electricity is derived from domestic uranium sources. The projections presume that 31 million KWh (net) of electricity are generated per ton of U_3O_8 (DOE 84d, pp. 76-77), and thus they presume that there is no significant increase in reactor or enrichment-plant efficiency; to the extent that such efficiency improvements may occur, the projections in Exhibit 3.9 should be revised upwards.

The projections shown in Exhibit 4-9 indicate that between 1.5 and 17.7 trillion KWh of electricity will be produced in 2085. The more extreme values in this range, however, represent relatively unlikely combinations of scenarios. A high percentage of electricity from domestic U_{235} sources, for example, would mean a relatively high reliance on domestic uranium and would probably result in sufficient increases in uranium prices to warrant use of higher-cost domestic uranium resources, as would occur under the alternate-case scenario. Conversely a low percentage of electricity from domestic U_{235} sources would mean more effective competition from other fuel sources (imported uranium, coal, etc.) and possibly the development of new electricity sources (e.g., fusion or the breeder reactor, though, by assumption, the development of these new

EXHIBIT 4-9:

PROJECTIONS OF TOTAL ELECTRICITY CONSUMPTION IN 2085 UNDER VARIOUS SCENARIOS

(trillions of KWh, net)

Percent of Electricity from Domestic U-235	Domestic U_3O_8 Production Scenario	
	Reference Case	Alternate Case (*)
25%	1.5	3.5
10%	3.7	8.8
5%	7.4	17.7
Approximate Number of 1 GWe Units Supported by Domestic U-235	60	150

N.B. These projections presume current reactor and enrichment-feed technology (See text).

(*) The most likely projections are those inside the box.

sources would not result in a significant reduction in the number of U_{235} power plants during the 100-year time period); under these circumstances, uranium prices would rise less and we would be less likely to tap the higher-cost resources which would be used under the alternate-case scenario.

In the light of the above discussion, the most likely projections of 2085 electricity consumption are those shown in the diagonal box in Exhibit 4-9. These projections suggest that between 3.5 and 8.8 trillion KWh of electricity will be consumed in 2085 (in comparison to the 2.3 trillion KWh consumed in 1984 (DOE 85d, p.77)).

In addition to the projections of electricity consumption, Exhibit 4-9 also shows the approximate number of one GWe nuclear power-plant units which would be supported by domestically produced U_{235} under each of the uranium-production scenarios (assuming a 66 percent average utilization rate). Approximately 60 units would be supported under the reference-case scenario and 150 units under the alternate-case scenario. It should be observed that a substantial (but undetermined) number of additional units would be supported by imported U_{235}.

Projected average annual rates of change in electricity consumption were obtained from the Exhibit 4-9 projections for 2085 and from DOE's projection of 2.32 trillion KWh for 1985 (DOE 85a, p. 214). The results are presented in Exhibit 4-10. These results range from an average decline of 0.4 percent per year to an average increase of 2.1 percent per year. For the most likely scenarios (those in the diagonal box), modest increases of 0.4 to 1.3 percent per year are indicated.

It is also possible to express the rates of change in electricity consumption on a per capita basis using any of several projections of population growth. The U.S. Bureau of the Census has recently published three series of population projections for the United States through the year 2080 (Cen 84). The middle series shows population growing from 232 million in 1982 to an essentially static 311 million in 2080. The lowest series shows population peaking at 263 million in 2017 and declining to 191 million in 2080; and the highest series shows population climbing to 531 million in 2080 (and increasing at a 0.7 percent annual rate during the last five years of this time period).

Using the middle series population projections, the United States population will rise from 232 million in 1982 to about 311 million in 2085. The average annual rate of

EXHIBIT 4-10:

AVERAGE ANNUAL PERCENTAGE CHANGE IN ELECTRICITY CONSUMPTION, 1985-2085

Percent Electricity from Domestic U-235	Domestic U_3O_8 Production Scenario: Reference Case	Domestic U_3O_8 Production Scenario: Alternate Case
25%	-0.4	+0.4 (*)
10%	+0.5 (*)	+1.3 (*)
5%	+1.2 (*)	+2.1

(*) The most likely projections are those inside the box.

population increase over this time period is 0.285 percent (though the actual rate of increase is initially much higher and declines to zero by the end of the period). Using this population series yields the projected average annual per capita rates of change in electricity consumption shown in Exhibit 4-11. These figures are just 0.285 percent smaller than the corresponding figures shown in Exhibit 4-10, and they range from a 0.7 percent annual decline to a 1.8 percent annual increase. For the most likely scenarios (those in the diagonal box), modest average annual increases of 0.1 to 1.1 percent are projected in per capita electricity consumption.

4.2 EMPLOYMENT PROJECTIONS

Exhibit 4-12 lists employment projections from 1985 to 2085 for the uranium milling industry. Projections are provided for the reference case and alternate case described earlier in this chapter. The reference case shows employment growing steadily from 1991 to 2085 after a relatively stagnant period from 1985 to 1991. The alternate case shows employment growing through 1992, declining steadily in 1993 and resuming growth thereafter.

The projections were developed in the following manner. Output-per-person-year was used as a measure of productivity. Data for this variable were obtained by dividing total annual uranium concentrate production from 1967 to 1984 by each year's total employment measured in person years, then averaging the results for the period (DOE 85e). The resulting productivity factor, 6.88 short tons per person-year, was then divided into the production forecasts summarized in Exhibit 4-7, "Total Domestic Production of U_3O_8: 1984-2085." Average historical productivity was considered suitable for use in projecting future employment because no technological changes in uranium processing that might affect mill productivity are expected.

4.3 DEVELOPMENT OF THE BASELINE

Chapter 3 presented data on the status of all existing impoundments. Many of the mills where these impoundments are located have been operating for over 25 years and have only limited remaining useful life. The acid-leach milling process utilized in this industry is a hostile environment for most machinery. While no definitive data are available on the expected remaining useful lives of the existing mills, it is assumed for this analysis that none of these facilities would be able to operate economically after the year 2000. Thus new mills and impoundments would have to be constructed on current mill sites or on new sites to meet the production scenarios developed in Section

EXHIBIT 4-11:

AVERAGE ANNUAL PERCENTAGE CHANGE IN PER CAPITA ELECTRICITY CONSUMPTION, 1985-2085

Percent of Electricity from Domestic U-235	Domestic U_3O_8 Production Scenario: Reference Case	Domestic U_3O_8 Production Scenario: Alternate Case
25%	-0.7	+0.1 (*)
10%	+0.2 (*)	+1.1 (*)
5%	+0.9 (*)	+1.8

(*) The most likely projections are those inside the box.

EXHIBIT 4-12:

EMPLOYMENT PROJECTIONS: 1985-2085

(Person-Years)

	Reference Case	Alternate Case
1985	262	262
1986	262	276
1987	269	291
1988	269	320
1989	276	349
1990	276	378
1991	276	392
1992	305	400
1993	356	371
1994	385	378
1995	407	451
1996	436	552
1997	465	654
1998	494	719
1999	509	749
2000	523	763
2001	533	789
2002	543	816
2003	554	844
2004	564	873
2005	575	902
2006	585	932
2007	596	963
2008	607	995
2009	618	1028
2010	630	1061
2011	641	1096
2012	653	1131
2013	665	1168
2014	677	1206
2015	689	1244
2016	701	1284
2017	714	1325
2018	726	1367
2019	739	1410
2020	752	1454
2021	765	1500
2022	778	1545
2023	791	1589
2024	803	1633
2025	815	1676
2026	828	1727
2027	842	1776
2028	855	1825
2029	867	1873
2030	880	1920
2031	891	1966
2032	903	2011
2033	914	2055
2034	925	2097

EXHIBIT 4-12:

EMPLOYMENT PROJECTIONS: 1985-2085 — (Continued)

(Person-Years)

	Reference Case	Alternate Case
2035	935	2139
2036	945	2180
2037	955	2220
2038	964	2258
2039	974	2296
2040	982	2332
2041	991	2368
2042	999	2403
2043	1007	2436
2044	1015	2469
2045	1022	2501
2046	1029	2531
2047	1036	2561
2048	1043	2590
2049	1049	2618
2050	1055	2645
2051	1061	2671
2052	1067	2697
2053	1072	2721
2054	1078	2745
2055	1083	2768
2056	1088	2790
2057	1093	2812
2058	1097	2833
2059	1102	2853
2060	1106	2872
2061	1110	2891
2062	1114	2909
2063	1118	2926
2064	1121	2943
2065	1125	2959
2066	1128	2975
2067	1132	2990
2068	1135	3004
2069	1138	3018
2070	1141	3032
2071	1143	3045
2072	1146	3057
2073	1149	3069
2074	1151	3081
2075	1153	3092
2076	1156	3103
2077	1158	3113
2078	1160	3123
2079	1162	3133
2080	1164	3142
2081	1166	3151
2082	1168	3160
2083	1170	3168
2084	1171	3176
2085	1173	3184

4.1 above. In actuality, many of those mills will cease being economic production options well before 2000 and some, with extensive maintenance and partial rebuilding may well be economic after 2000.

While many configurations of mills are possible for future facilities, this report utilizes the NRC model mill and impoundment for all future new mills. The model mill is thoroughly described in the Background Information Document (EPA 86, References Chapter 3). This model mill is consistent with the model mill utilized in previous analysis of final stabilization standards under other ORP and NRC rulemakings.

When a licensed mill is not operating, it is considered to be on standby. Licensing authorities may require that a limited dust cover (usually about one foot of earth) be placed on the tailings piles to prevent extensive blowing of dry tailings during standby periods. Radon emission levels may not be substantially effected by this limited cover. In the past, mills have remained on standby for long periods of time. Today, only 2 of the 27 licensed mills are operating, the balance are on standby or preparing for decommissioning. When a mill owner decides to terminate an operating license, the decommissioning of the mill and final stabilization of the tailings impoundments will occur. For the purpose of the baseline it is assumed that a period of 45 years after ceasing operation occurs before stabilization. While the period of 5 years of wet tailings and 40 years of dry tailings appears consistent with current practices, a sensitivity run with only 20 years of dry tailings is presented in subsequent analysis.

Section 4.1 develops two future production scenarios, a reference case developed from the DOE low production scenario and an alternate case developed from the DOE mid-production case. These forecasts are very similar between now and the year 2020 as they are based on the stock of nuclear power plants in operation or currently nearing completion. The basic difference in the forecasts is the expected cancellations of plants currently on order and the time period before new orders are again placed. Such assumptions are purely speculative. Substantial variance in these forecasts could easily be supported through adjustments in these assumptions. Both cases imply that nuclear power will continue to provide a substantial portion of our future electric generation needs. The low case provides for utilization of all existing facilities in 2010. These new new orders will replace existing nuclear capacity and add additional nuclear capacity over time. This scenario was selected as the reference case as a conservative judgement about the future of nuclear power. The alternate case with a greater shift to nuclear power in the future provides a sensitivity to the conservative assumption about the future of nuclear power.

Given the assumption about the expected useful life of existing mills and impoundments and a 15 year operating life for new model mills, the specific number of mills required to meet the reference and alternate case production scenarios can be developed. Exhibit 4-13 presents the number of existing and new mills operating and coming on line by five year period for the next 100 years. Mills operating from 1985-2000 are all existing mills and, by assumption, they are all replaced by new mills in 2000. It should be noted that it requires eight and eleven new model mills for the reference and alternate cases to replace the capacity of the existing mills that stopped operation in 2000. As the operating life of a model mill is fixed at 15 years, this results in an artificial periodic capacity replacement cycle for this new year 2000 capacity that repeats every 15 years through year 2085.

Given the reference case production forecast presented in Section 4.1 above and the estimates of emissions for existing impoundments in Chapter 3, the profile of the expected fatal lung cancer for current and future impoundments can be developed. Using emissions data on existing impoundments and estimates of emissions of model impoundments for future sites, Exhibit 4-14 presents expected future cancers by type of impoundment and region of impact over the next 100 years. Exhibit 4-15 identifies the state in which the emissions occur for existing impoundments. Total fatal cancers shown in these exhibits are a result of the emissions from all existing impoundments or those constructed over the next 100 years. The period post-2085 is the emissions and fatal lung cancers from impoundments constructed in or prior to 2085 and still operating or on standby after 2085 awaiting final stabilization.

EXHIBIT 4-13:

NUMBER OF EXISTING TAILINGS IMPOUNDMENTS IN USE AND NEW MILLS/IMPOUNDMENTS OPENED BY PERIOD FOR THE REFERENCE CASE(*) AND THE ALTERNATE CASE(**)

	Reference Case		Alternate Case	
Period	In Use	Opened	In Use	Opened
1986-90	4		4	
1991-95	4		4	
1996-00	3		3	
2001-05	8	8	11	11
2006-10	9	1	13	2
2011-15	10	1	15	2
2016-20	11	9	18	14
2021-25	12	2	21	5
2026-30	13	2	23	4
2031-35	14	10	26	17
2036-40	14	2	28	7
2041-45	15	3	30	6
2046-50	15	10	32	19
2051-55	16	3	34	9
2056-60	16	3	35	7
2061-65	17	11	36	20
2066-70	17	3	37	10
2071-75	17	3	37	7
2076-80	17	11	38	21
2081-85	17	3	39	11

(*) Reference Case: Low Production
(**) Alternate Case: High Production

EXHIBIT 4-14:

ESTIMATED COMMITTED FATAL LUNG CANCERS FROM RADON-222 EMISSIONS FROM EXISTING AND FUTURE TAILINGS IMPOUNDMENTS

Location of Impoundment	TIME PERIOD COMMITTED						
	1985-2005	2006-2025	2026-2045	2046-2065	2066-2085	Post 2085[b]	Total[a]
Existing Impoundments							
Local Effects							
0-5 kilometers	3	4	1	.1	.1		9
5-80 kilometers	30	30	10	1	1		70
Total Local	33	34	11	1	1		79
National Effects	50	60	22	2	2		136
Total Effects	81	92	34	3	3		214
New Impoundments							
Local Effects							
0-5 kilometers	.02	.3	1	3	3	6	14
5-80 kilometers	.2	3	10	20	20	40	101
Total Local	.2	3	10	20	30	50	114
National Effects	.4	5	20	40	50	90	198
Total Effects	.6	8	30	60	80	137	312
All Impoundments							
Local Effects							
0-5 kilometers	3	4	3	3	3	6	22
5-80 kilometers	30	30	20	20	30	40	171
Total Local	30	40	20	20	30	50	193
National Effects	50	60	40	40	50	90	333
Total Effects	82	101	65	62	78	137	526

[a] Individual items may not add to total due to rounding.

[b] Fatal lung cancers from piles uncovered in 2085 until they reach final cover.

EXHIBIT 4-15:

ESTIMATED FATAL LUNG CANCERS FROM EMISSIONS OF RADON-222 FROM EXISTING AND FUTURE TAILINGS IMPOUNDMENTS, BY STATE OF ORIGIN

Location of Impoundment	TIME PERIOD COMMITTED 1986-2005	2006-2025	2026-2045	2046-2065	2066-2085	Post 2085[a]	Total
EXISTING IMPOUNDMENTS							
Colorado							
0-80 km	3	5	4	.2	.2		—
National	3	5	3	.2	.2		—
Total	6	10	7	.3	.3		24
New Mexico							
0-80 km	20	22	7	.6	.6		—
National	27	30	10	.8	.8		—
Total	47	51	17	1	1		117
Texas							
0-80 km	2	2	.6	.2	.2		—
National	.7	.7	.2	.07	.07		—
Total	2	3	.8	.3	.3		6
Utah							
0-80 km	1	1	.5	.06	.06		—
National	5	7	2	2	.2		—
Total	6	7	3	.3	.3		17
Washington							
0-80 km	3	3	.3	.09	.09		—
National	4	4	.5	.1	.1		—
Total	7	7	.8	.2	.2		15
Wyoming							
0-80 km	.7	.9	.4	.04	.04		—
National	11	14	6	.7	.7		—
Total	12	15	6	.7	.7		34
Total Existing Impoundments	81	93	34	3	3		214
New Impoundments							
0-80 km	.2	3	11	22	27	50	—
National	.4	5	20	37	47	87	—
Total	.6	8	31	59	78	137	312
Total All Impoundments	82	101	65	62	84	137	526

[a] Fatal lung cancers from piles uncovered in 2085 until they reach final cover.

[b] Individual items may not add to total due to rounding.

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CHAPTER 5:

ALTERNATIVE WORK PRACTICES FOR MILL TAILINGS IMPOUNDMENTS

The reduction of radon-222 emissions from licensed uranium mills is most effectively accomplished by managing the tailings impoundments because radon-222 emissions from the milling circuit are relatively small and are not readily controlled. For mills which are not operating and are on a standby basis, nearly all the radon-222 emissions come from the tailings disposal area.

In this chapter the control techniques available for reducing radon emissions at mill tailings impoundments are discussed. This is followed by a detailed discussion of controls for existing impoundments and impoundments to be constructed in the future.

5.1 DESCRIPTION OF WORK PRACTICES

Radon emissions from uranium mill tailings can be reduced by minimizing or covering tailings dry beach areas. Dry beach can be minimized by keeping the tailings covered with fluids. Earth or synthetic material can be used in cases where fluid cover is not practical. For new tailings impoundments, staged or phased disposal of the tailings or dewatering and covering are also ways of limiting the area of exposed tailings. Extraction of radium from the tailings, chemical fixation, and sintering of tailings as a means of reducing radon emissions have also been explored, but have not been applied on a large scale and appear too costly for general application (NRC80). The applicability and effectiveness of control techniques are, for the most part, dependent upon the design of the mill tailings impoundments and the mill's operating schedule. Thus, the control techniques can be broadly classified as applicable to -- 1) existing tailings impoundments at existing uranium mills, and 2) new tailings impoundments at either new or existing uranium mills.

5.1.1 Earth Cover

Covering the dried beach area with dirt is an effective method for reducing radon-222 emissions and is being used at inactive tailings impoundments. The depth of soil required for a given amount of control varies with the type of earth and the tailings radon-222 exhalation rate.

Earth cover is useful in decreasing radon-222 emissions because it detains radon-222 long enough that it will decay in the cover. A rapid decrease in radon-222 emissions is initially achieved by applying almost any type of earth. The high-moisture content earths provide greater radon-222 emission reduction because of their smaller diffusion coefficient.

In practice, earthen cover designs must take into account uncertainties in the measured values of the specific cover materials used, the tailings to be covered, and predicted long-term values of equilibrium moisture content for the specific location. The uncertainty in predicting reductions in radon-222 flux increases rapidly as the required radon-222 emission limit is reduced.

The cost of adding earth covers varies widely with location of the tailings impoundment, its layout, availability of earth, the topography of the disposal site, its surroundings, and hauling distance. Another factor affecting costs of cover material is its ease of excavation. In general, the more difficult the excavation, the more elaborate and expensive the equipment and the higher the cost. The availability of materials such as clay or sand will also affect costs. If the necessary materials are not available locally they must be purchased and/or hauled and costs could increase significantly.

5.1.2 Water Cover

Maintaining a water cover over the tailings reduces radon-222 emissions. The degree of radon-222 control increases with the depth of the water and decreases with the radium-226 content of the water. Factors affecting this practice include the mill water recirculation rate (if any), evaporation and precipitation rates, pile construction and slope, phreatic levels and precipitation rates, pile construction and slope, groundwater contamination, and dike or dam stability. Some above-ground tailings piles minimize the depth of water in the pond to reduce seepage and possible groundwater contamination by draining the water through an overflow pipe to a separate lined evaporation pond.

The diffusion coefficient of water is very low (about one thousandth that of a 9 percent moisture content soil) and water is thus an effective barrier for radon-222. In shallow areas, however, radon-222 release is increased by thermal gradients and wave motion and emissions approach those of saturated tailings. Increased radium-226 content in the water reduces its effectiveness in controlling radon-222 since it releases radon-222. For a water depth less than 1 meter, the radon flux is similar to saturated bare tailings.

If a tailings impoundment is initially designed and built to maintain a water cover, there is no added cost for this form of radon-222 control. Continued monitoring is required to determine if there is any seepage through the dam or sides, and groundwater samples may be required peridocially as a check for contamination from seepage. However, if the tailings impoundment is not designed to maintain a water cover, this form of work practice may be undesirable as it may cause groundwater contamination. For the purpose of this analysis saturated and ponded areas are assumed to have negligible emissions.

5.1.3 Water Spraying

Water (or tailings liquid) sprays can be used to maintain a higher level of moisture in the tailings beach areas. This reduces fugitive dust emissions and may reduce the loss of radon-222 from the tailings. The effectiveness of this method, however, varies with the moisture content of the tailings. The radon-222 emanation coefficient initially increases with increasing moisture content up to about 5-10 percent moisture by weight and then remains fairly constant. Thus, if water is applied to a very dry beach area, radon-222 emissions would initially increase until the emanation becomes constant. Increased moisture after that point decreases diffusion and thus decreases radon-222 emissions (St 82). Over longer periods of time, an overall radon-222 reduction of 20 percent has been estimated (NRC80). The overall feasibility of wetting to achieve significant radon-222 reductions is questionable, especially in arid regions, since large quantities of liquid are required to maintain high moisture levels.

5.1.4 Synthetic Covers

Synthetic material such as a polyethylene sheet can also reduce radon-222 emissions if carefully placed and sealed on dry beach areas. Covering could be used on portions of the tailings area on a temporary basis and then removed or covered with fresh tailings. Such a barrier would also, at least temporarily, aid in the control of radon-222 if a soil cover material is applied. The overall effectiveness of synthetic covers is not known since leaks occur around the edges and at seams and breaks. Synthetic covers have a limited life, especially in dry, sunny, windy areas and will not provide a long-term barrier to radon-222. Chemical stabilization sprays that form coatings on the dry tailings are effective for controlling dust, but are not too useful for suppressing radon-222 since an impermeable cover is not obtained.

5.1.5 Thermal Stabilization

Thermal stabilization is a process in which tailings are sintered at high temperatures. The Los Alamos National Laboratory has conducted a series of tests on tailings from four different inactive mill sites (Dr81). The results showed that thermal stabilization was effective in preventing the release (emanation) of radon from tailings. The authors note that before thermal stabilization can be considered as a practical disposal method, information is needed on the following: (1) the long-term stability of the sintered material; (2) the interactions of the tailings and the refractory materials lining a kiln; (3) the gaseous and particulate emissions produced during sintering of tailings; and (4) revised engineering and economic analysis as more information is developed.

Since gamma radiation is still present, protection against the misuse of sintered tailings is required. While the potential health risk from external gamma radiation is not as great as that from the radon decay products, it can produce unacceptably high exposure levels in and around occupied buildings. Also, the potential for groundwater contamination may require the use of liners in a disposal area.

5.1.6 Chemical Processing

The Los Alamos National Laboratory has also studied various chemical processes to extract thorium-230 and radium-226 from the tailings, along with other minerals (Wm81). After removal from the tailings, the thorium and radium can be concentrated and fixed in a matrix such as asphalt or concrete. This greatly reduces the volume of these hazardous materials and allows disposal with a higher degree of isolation that economically achievable with tailings.

The major question regarding chemical extraction is whether it reduces the thorium and radium values in the stripped tailings to safe levels. If processing efficiencies of 80 percent to 90 percent were attained, radium concentrations in tailings would still be in the 30 to 60 pCi/g range. Thus, careful disposal of the stripped tailings would still be required to prevent misuse. Another disadvantage of chemical processing is the cost, although some of the costs might be recovered from the sale of other minerals recovered in the processing (Th81).

5.1.7 Soil Cement Covers

A mixture of soil and Portland cement, called soil cement, is widely used for stabilizing and conditioning soils (PC79). The aggregate sizes of tailings appear suitable for soil cement, which is relatively tough, withstands freeze/thaw cycles, and has a compressive strength of 300 to 800 psi. When combined in a disposal system with a 1-meter earth cover over it, soil (tailings) cement would likely provide reasonable resistance to erosion and intrusion, substantially reduce radon releases, and shield against penetrating radiation. Its costs are expected to be comparable to those of thick earth covers. The long-term performance of soil cement is unknown, especially as tailings piles shift or subside with age. Also, soil cement cracks at intervals when placed over large surface areas. The importance of this cracking on the effectiveness of soil cement has not been evaluated, but is expected to be small.

5.1.8 Deep-Mine Disposal

Disposal of tailings in worked-out deep mines offers several advantages and disadvantages compared to surface disposal options. The probability of intrusion into and misuse of tailings in a deep mine is much less than that achievable with surface disposal. Radon releases to the atmosphere would be eliminated, for practical purposes, as would erosion and external radiation. Overall, this method is costly, provides a relatively high level of protection from 85 percent of the radioactivity in the tailings, but provides little protection from the remaining radioactivity and toxic materials unless additional controls are used.

5.2 WORK PRACTICES FOR EXISTING TAILINGS IMPOUNDMENTS

At licensed mills, tailings impoundments may have reached capacity or be unused during standby periods. To reduce radon-222 emissions, impoundments that will not be used again could be covered with earthen material prior to mill decommissioning. For mills that are on standby, a cover (soil or synthetic material) could be applied to dry-beach areas and, in some cases, water cover could be maintained to reduce emissions.

The reduction of radon-222 emissions from active tailings impoundments depends on the specific characteristics of the milling process and the impoundment. These characteristics include: layout and dike construction, dike height and stability, phreatic level and permeability, type of milling process (acidic or alkali), plant water balance, pond evaporation rates, and availability of suitable earth cover material. Operating factors such as expected production rate, length and number of standby periods, pond capacity, and expected mill life also affect the controls that could be selected.

At active impoundments, only those portions that are not to be used further could be covered. Which portion and how much of the tailings area to cover is a function of anticipated mill life and quantity of tailings, size of tailings pile, and level of tailings (percent of capacity). In addition, a source of cover material must be obtained and a technique must be developed for hauling, dumping, spreading and compacting the soil onto the beach area. The limited access to the tailings area and the stability of the dike may affect the size of the equipment that can be used to transport and spread the cover material. Additional soil may have to be added to the dam or embankments to decrease their slope and increase stability. Metal gratings or timbers may be required to distribute vehicle wheel loads on the dike or dried beach area to facilitate the use of earthmoving equipment.

For existing tailings impoundments water cover is assumed not to be a feasible radon-222 control strategy. The feasibility of water cover is limited because of the high likelihood of groundwater contamination and dike stability and seepage. Also, during extended standby periods maintaining the water cover will be difficult, especially in arid areas. If water cover is to be practiced, the impoundment should be lined and constructed to allow at least a 1-meter depth water cover with an overflow pipe leading to an adjacent evaporation pond and/or recycling to the mill. To use water cover, sufficient freeboard must be maintained to prevent overflow and ground water monitoring may be required.

5.3 WORK PRACTICES FOR NEW TAILINGS IMPOUNDMENTS

Tailings impoundments to be constructed in the future must, at minimum, meet current Federal standards for prevention of groundwater contamination and airborne particulate emissions. This baseline tailings impoundment will have synthetic or clay liners, will probably be built below or partially below grade and have earthen dams or embankments to facilitate decommissioning. A means for dewatering the tailings after the area is full should also be incorporated. This conventional design allows the maintenance of a water cover over the tailings during the milling and standby periods thus maintaining a very low level of radon-222 emissions. Dewatering of the tailings can be accelerated using wells and or built-in drains. A clay or synthetic liner is placed along the sides and bottom. Cover material may be added after the impoundment has reached capacity or is not going to be used further and the tailings have dried. For the baseline model new impoundment it is assumed that final cover will be added forty years after the tailings have dried. Sensitivity to the assumption of the forty year dry period is evaluated in the sensitivity analysis contained in Chapter 6. Three alternatives to the work practices assumed in this baseline model new tailings impoundment are evaluated in this analysis. These alternatives are discussed in the following sections.

5.3.1 Single Cell Impoundment With Immediate Cover

The first alternative work practice for new impoundments which was evaluated consisted of the construction of the baseline single cell tailings impoundment with the sole change being a requirement that the final cover is applied to the exposed tailings as soon as they have dried. It is assumed that the tailings will be completely dried five years after the impoundment has reached capacity. Because the baseline impoundment requires a means for dewatering the tailings, five years is a reasonable time period for drying.

5.3.2 Phased Disposal

The second alternative work practice which was evaluated for model new tailings impoundments was phased disposal. In phased or multiple cell disposal, the tailings impoundment area is partitioned into cells which are used independently of other cells. After a cell has been filled, it can be dewatered and covered, and another cell used. Tailings are pumped to one initial cell until it is full. Tailings are then pumped to a newly constructed second cell and the former cell is dewatered and then left to dry. After the first cell drys, it is covered with earth obtained from the construction of a third cell. This process is continued sequentially. This system minimizes emissions at a given time since a cell can be covered after use without interfering with operation as opposed to the case of a single cell. Standby periods do not present a problem and construction of new cells can easily be postponed. Less total surface area is thus exposed at any one time. When the tailings impoundment has reached capacity, the entire area is graded and eventually covered with soil to meet Federal requirements.

Phased disposal is effective in reducing radon-222 emissions since tailings are initially covered with water and finally with earth. Only during a drying-out period of about 5 years for each cell are there any radon-222 emissions from a relatively small area. During mill standby periods, a water cover could be maintained on the operational cell. For extended standby periods, the cell could be dewatered and a dirt or synthetic cover applied.

5.3.3 Continuous Disposal

The third alternative work practice, continuous disposal, is based on the fact that water can be removed from the tailings slurry prior to disposal. The relatively dry dewatered (25 to 30% moisture) tailings can then be dumped and covered with soil almost immediately. No extended drying phase is required and very little additional work would be required during final closure per Federal requirements. Additionally, ground water problems are minimized. To implement a dewatering system would require added planning, design, and modification of current designs. Acid-based leaching processes do not generally recycle water, and additional holding ponds with ancillary piping and pumping systems would be required to handle the liquid removed from the tailings. Using trucks or conveyor systems to transport the tailings to disposal areas might also be more costly than slurry pumping. Thus, although tailings are more easily managed after dewatering, this practice would have to be carefully considered on a site-specific basis.

Various filtering systems such as rotary vacuum and belt filters are available and could be adapted to a tailings dewatering system. Experimental studies would probably be required for a specific ore to determine the filter media and dewatering properties of the sand and slime fractions. Modifications to the typical mill ore grinding circuit may be required to allow efficient dewatering and to prevent filter plugging or blinding. Corrosion-resistant materials would be required in any tailings dewatering system due to the highly corrosive solutions which must be handled. Continuous tailings dewatering is not practiced at any uranium mills in the United States, but it was proposed at several sites in the Southwestern and Eastern United States (Ma83). Tailings dewatering systems have been used successfully at nonferrous ore beneficiation mills in the United States and Canada (Ro78).

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CHAPTER 6:

ESTIMATED BENEFITS AND COSTS OF ALTERNATIVE WORK PRACTICES

This chapter provides an overview of the benefits and costs of the alternative work practices introduced in the preceding chapter. Costs are estimated as the sum of direct and indirect costs. Direct costs are based on conventional engineering estimates for excavation, hauling, grading, etc. Indirect costs, which are estimated as 32 percent of direct costs, are assumed to include the costs of engineering design, permit costs, subcontractor's fees, and a contingency. Benefits are provided in terms of levels (or reductions in levels) of emissions and total cancers which result from the various work practices.

The costs of the various alternative work practices are discussed in the first section of the chapter while the benefits are discussed separately in the second section. Within each section work practices applicable to new model tailings impoundments are discussed first and work practices employed at existing tailings impoundments are discussed second. Total costs and benefits under various regulatory alternatives given the reference case assumptions are presented in the third section. The sensitivity of the estimated total costs and benefits to a change in the reference case baseline dry period before final stabilization in the absence of EPA action from 40 years to 20 years is examined in the following chapter.

6.1 COST OF ALTERNATIVE PRACTICES

6.1.1 New Model Tailings Impoundments

The estimated costs of the three alternative types of model new tailings impoundments (single cell, phased disposal, and continuous disposal) with below-grade and partially-below-grade design are provided in Exhibits 6-1 and 6-2. Below grade model new tailings impoundments were evaluated in this analysis because they are recommended under current Federal regulations. (In the sensitivity analysis presented in Chapter 8, costs for partially below grade impoundments are examined.) All costs are given in 1985 dollars. Estimates are given separately for each direct cost component (e.g., excavation). An indirect cost component, estimated as 32 percent of direct cost is added in to provide total cost. Direct costs at all three types of new model

EXHIBIT 6-1

ESTIMATED COSTS OF BELOW-GRADE MODEL NEW TAILINGS IMPOUNDMENTS[a/]
(Millions of 1985 Dollars)

Item	Single Cell Impoundment	Phased Disposal		Continuous Disposal (trench design)
		Each Cell	All Cells[b/]	
Excavation	21.51	3.68	22.08	22.75
Synthetic liner (30 mil)	3.03	0.57	3.40	3.82
Grading	0.40	0.07	0.45	0.51
Drainage system	0.40	0.07	0.40	-
Cover(3 m)	4.05	0.76	4.57	5.15
Gravel cap (0.5 m)	1.92	0.37	2.21	2.54
Evaporation pond	-	0.52	3.09	4.80
Vacuum filter	-	-	-	1.46
Subtotal direct cost	31.31	6.04	36.20	41.03
Indirect cost[c/]	10.02	1.93	11.58	13.13
Total cost	41.33	7.97	47.78	54.16

a/Below-grade impoundments are constructed so that the top of the final cover is at grade.

b/Six cells of 20 acres are assumed.

c/Indirect costs including design, engineering, management, planning contingencies, etc. are estimated to be 32 percent of direct costs.

EXHIBIT 6-2

ESTIMATED COSTS OF PARTIALLY BELOW-GRADE MODEL NEW TAILINGS IMPOUNDMENTS[a/]
(Millions of 1985 Dollars)

Item	Single Cell Impoundment	Phased disposal: Each Cell	Phased disposal: All Cells[b/]	Continuous[c/] Disposal (single cell design)
Excavation	8.14	1.28	7.70	8.14
Synthetic liner (30 mil)	3.03	0.57	3.40	3.03
Grading	0.40	0.07	0.45	0.40
Drainage system	0.40	0.07	0.40	-
Dam construction	2.75	1.27	7.61	2.75
Cover (3 m)	4.05	0.76	4.57	4.05
Rip-rap on slopes (0.5 m)	1.74	0.32	1.91	1.74
Gravel cap (0.5 m)	1.99	0.39	2.34	1.99
Evaporation pond	-	0.52	3.09	4.80
Vacuum filter	-	-	-	1.46
Subtotal direct cost	22.5	5.25	31.47	28.36
Indirect cost[d/]	7.21	1.68	10.07	9.08
Total cost	29.7	6.93	41.54	37.44

[a/] Partially below-grade impoundments are constructed so that tailings are half below and half above grade. Slopes of dams are 5:1 (h.v.). Earth for dam construction and cover is taken from impoundment excavation and borrow-pits when necessary.

[b/] Six cells of 20 acres are assumed.

[c/] A single cell design is used for partially below grade continuous disposal since this is the more economical option.

[d/] Indirect costs including design, engineering, management, planning contingencies, etc. are estimated to be 32 percent of direct costs.

impoundments include components for excavation, synthetic liners, grading 3 meters of cover, and 0.5 meters of gravel cap. The single cell and phased disposal impoundments also include costs for a drainage system. The continuous disposal impoundment does not require a drainage system as the tailings are dry prior to being placed in the impoundment. In addition, the phased and continuous impoundments include an evaporation pond cost component and the continuous impoundment a vacuum filter cost component.

The phased and continuous disposal practices limit airborne radon-222 emissions by reducing the area of exposed dry tailings during operations and by providing the opportunity for covering substantial portions of the tailings earlier than would occur using current disposal practices. The total real resource cost for the proposed work practices are somewhat higher than for traditional methods of disposal, and these costs are expended more uniformly over the operating life of the impoundments. By comparison, the current large impoundment method of disposal requires large up-front costs for excavation and large rear-end costs for final stabilization. Estimated real 1985 dollar costs for below grade disposal at the model new impoundment are shown in Exhibit 6-3. In this exhibit, costs for each technology are separated into five-year periods, with period 1 beginning in the current year. The impoundment is active during periods 1, 2 and 3. Period 4 represents a 5-year drying period for single cell and phased disposal. The fifth period is required for final stabilization. Real resource cost streams for each alternative were estimated for entirely below-grade impoundments. The present value columns of the exhibit show the sum (undiscounted) and the present value of the cost streams using a 5 percent or 10 percent real rate of discount. For purposes of calculating the present values, all costs were treated as occurring at the beginning of the appropriate 5-year period; e.g., period 1 costs are treated as current costs and period 5 costs are incurred 20 years from the present time. Undiscounted costs for phased and continuous disposal exceed costs for the single cell impoundment method. However the present values calculated at a 5 percent real discount rate show that phased disposal is slightly less expensive than the single cell impoundment which is chosen to be the baseline. At a 10 percent real discount rate, phased disposal is significantly less expensive than the baseline. Continuous disposal, which costs approximately $13 million more than the baseline impoundment with no discount, is only $1.5 million more expensive at a 10 percent real discount rate.

EXHIBIT 6-3

CONSTRUCTION AND COVER COST STREAM AND PRESENT VALUE FOR ALTERNATIVE MODEL NEW TAILINGS IMPOUNDMENTS (BELOW-GRADE)[a/]

(Millions of 1985 Dollars)

Alternatives	Construction and Cover Cost by Operating Period (Years from Start of Operations)					Present Value of[b/] Construction and Cover Cost at Various Discount Rates		
	0-4 Years	5-9 Years	10-14 Years	15-19 Years	20-24 Years	0% Discount	5% Discount	10% Discount
Single Cell Impoundment	33.45	0.00	0.00	0.00	7.88	41.33	36.42	34.62
Phased Disposal	12.96	14.45	15.95	2.98	1.49	47.84	36.07	29.02
Continuous Disposal	18.04	18.04	18.04	0.00	0.00	54.13	43.26	36.21

a/ A limited amount of operation and maintenance cost would also be anticipated during impoundment life but these costs are small, when compared with construction and cover costs.

b/ Costs are assumed to occur at beginning of five-year period.

This reduction in cost difference between the recommended and traditional disposal methods at higher rates of discount is due to the delay in the timing of large expenditures for excavation when a phased or continuous method of disposal is employed. The effect is markedly more pronounced for entirely below-grade impoundments, since in this case the baseline impoundment has a higher share of front-loaded excavation costs than in the partially below-grade case. Further refinement of the cost stream to annual expenditures would further reduce the differences in present value cost.

6.1.2 Existing Tailings Impoundments

For existing tailing impoundments two work practices were evaluated: final cover and interim cover. Water management or water cover was not evaluated because most existing piles were not of proper design for this work practice. Most notable is the lack of liners at all but three of the existing impoundments. Use of water management in the absence of liners would most likely result in unacceptable groundwater contamination risks.

The cost of a final cover was evaluated for each existing tailings impoundment, with the exception of evaporation ponds. Tailings in the evaporation ponds are assumed to be excavated and moved to one of the primary tailings piles at the site. Final cover is assumed to be a dirt covering of the depth required to reduce emissions to 20 pCi/m^2-sec.

Exhibit 6-4 provides the cost of final cover for each existing tailings pile in 1985 dollars. For each pile, Exhibit 6-4 provides background information on the type of pile, status of the pile, total acres in the pile, and depth of final cover required to meet the standard of 20 pCi/m^2-sec. Direct costs for final cover are presented separately for grading slopes, covering the pile to the specified depth, placing gravel and rip-rap to prevent erosion, tampering etc., reclaiming borrow pits, excavating evaporation ponds (for evaporation ponds only). Indirect costs are estimated at 32 percent of direct costs and are added to direct costs to provide total cost.

In addition, an interim cover of one meter depth was evaluated using various assumptions concerning which areas of the piles (i.e. dry versus wet areas) would be covered. Interim cover is assumed to be a simple one meter dirt cover whose cost

EXHIBIT 6-4

COSTS OF FINAL COVER OPTION ON EXISTING PILES ($M.1985)

Site/ Pile	Type of pile a/	Status of pile b/	Total area, ac	Depth of final cover, m	Grade slopes	Cover to 20 pCi/m2s	Gravel & rip-rap	Reclaim borrow pit	Excavate evap ponds	Total direct cost	Indirect costs, 32%	Total cost
Colorado												
Cotter Corp.												
Primary	2	S	84	3.8		9.12	1.47	0.40		10.99	3.52	14.51
Secondary	2	C	31	3.8		3.37	0.54	0.17		4.08	1.31	5.39
Umetco												
Pile 1 & 2	1	C	66	3.3	1.88	15.40	8.33	0.65		26.26	8.40	34.66
Pile 3	1	C	32	3.3	0.82	6.04	3.18	0.28		10.32	3.30	13.62
Sludge pile	1	C	20	3.3	0.1	1.88	0.35	0.11		2.44	0.78	3.22
Evap. pond	1	C	17						0.48	0.48	0.15	0.64
New Mexico												
Sohio												
L-Bar	1	S	128	3.4	0.46	14.50	4.43	0.61		20.00	6.40	26.40
United Nuclear												
Churchrock	1	S	148	2.8	0.5	13.40	4.72	0.57		19.19	6.14	25.33
Anaconda												
Bluewater 1	2	S	239	3.6		24.32	4.18	0.98		29.48	9.43	38.91
Bluewater 2	2	C	47	3.6		4.78	0.82	0.23		5.84	1.87	7.70
Bluewater 3	2	C	24	3.6		2.44	0.42	0.13		2.99	0.96	3.95
Evap. ponds	2	S	162						4.59	4.59	1.47	6.06
Kerr-McGee												
Quivira 1	1	S	269	3.6	0.85	34.30	10.20	1.35		46.70	14.94	61.64
Quivira 2a	1	S	105	3.6	0.53	12.74	3.88	0.54		17.69	5.66	23.35
Quivira 2b	1	S	28	3.6	0.01	2.85	0.49	0.15		3.50	1.12	4.62
Quivira 2c	1	S	30	3.6	0.01	3.05	0.52	0.16		3.75	1.20	4.95
Evap. ponds	2	S	372						10.54	10.54	3.37	13.91
Homestake												
Homestake 1	1	S	205	3.1	1.4	36.50	18.36	1.43		57.69	18.46	76.15
Homestake 2	2	C	44	3.1		3.86	0.77	0.19		4.82	1.54	6.36
Texas												
Chevron												
Panna Maria	2	S	124	2.4		8.39	2.17	0.38		10.93	3.50	14.43
Utah												
Umetco												
White Mesa	3	S	48	3.0		4.07	0.84	0.20		5.11	1.64	6.75
White Mesa	3	S	61	3.0		5.17	1.07	0.25		6.49	2.08	8.56
White Mesa	3	S	53	3.0		4.50	0.93	0.22		5.64	1.81	7.45

EXHIBIT 6-4(cont.)

COSTS OF FINAL COVER OPTIONS ON EXISTING PILES ($M.1985)

Site/ Pile	Type of pile a/	Status of pile b/	Total area, ac	Depth of final cover, m	Grade slopes	Cover to 20 pCi/m2s	Gravel & rip-rap	Reclaim borrow pit	Excavate evap ponds	Total direct cost	Indirect costs, 32%	Total cost
Rio Algom												
Rio 1	2	A	44	3.5		4.34	0.77	0.21		5.33	1.70	7.03
Rio 2	2	A	32	3.5		3.16	0.56	0.16		3.88	1.24	5.13
Atlas												
Moab	1	S	147	3.4	1.1	24.10	10.29	1.00		36.49	11.68	48.17
Plateau Res												
Shootering	2	S	7	2.8		0.55	0.12	0.04		0.71	0.23	0.94
Washington												
Dawn Mining												
Ford 1,2,3	2	C	95	3.9		7.42	1.66	0.46		9.54	3.05	12.59
Ford 4	3	S	28	3.9		2.19	0.49	0.16		2.84	0.91	3.75
Western Nuclear												
Sherwood	2	S	94	2.4		6.41	1.64	0.30		8.35	2.67	11.03
Evap. pond	2	S	16						0.45	0.45	0.15	0.60
Wyoming												
Pathfinder												
Gas Hills 1	2	S	124	3.2		11.19	2.17	0.48		13.84	4.43	18.27
Gas Hills 2	2	C	54	3.2		4.87	0.94	0.23		6.05	1.94	7.99
Gas Hills 3	2	S	22	3.2		1.98	0.38	0.11		2.48	0.79	3.28
Gas Hills 4	2	S	89	3.2		8.03	1.56	0.36		9.95	3.18	13.13
Western Nuclear												
Split Rock	2	S	156	3.2		14.18	2.73	0.60		17.51	5.60	23.11
Umetco												
E. Gas Hills	2	C	151	2.9		12.26	2.64	0.53		15.43	4.94	20.37
A-9 Pit	3	S	25	2.9		2.03	0.44	0.11		2.58	0.83	3.41
Leach pad	2	S	22	2.9		1.79	0.38	0.10		2.27	0.73	3.00
Evap ponds	2	S	20						0.57	0.57	0.18	0.75
Rocky Mountain Energy												
Bear Creek	2	S	121	3.2		10.92	2.12	0.47		13.51	4.32	17.83
Pathfinder												
Shirley Basin	2	A	261	3.4		25.49	4.56	1.02		31.08	9.94	41.02
Minerals Exp.												
Sweetwater	2	S	37	2.8		2.89	0.65	0.15		3.69	1.18	4.87
TOTALS			3882		7.7	355	102	16	17	496	159	655

Note: Dams constructed of tailings are graded to a 5h: 1v slope, 0.45m of gravel is applied to the tops of all impoundments and 0.45m of rip-rap is applied to the slopes of dams constructed of tailings. Cover material is excavated on site, borrow pit is reclaimed. Evaporation ponds are excavated and material placed on tailings impoundment before cover.

a/ Type of impoundment: 1 = dam constructed of coarse tailings; 2 = earthen dam; 3 = below grade.

b/ Status of impoundment: A = active; S = standby (will be used when operations resume); C = filled to capacity (will not be used again).

varies in direct portion to the area of the pile which is to be covered. The cost of interim cover includes components for excavation, hauling, etc. expressed in terms of a cost per unit of area. A factor of 32 percent for indirect costs is included. The total costs of the alternative interim cover strategies are shown in Exhibit 6-5 in 1985 dollars. Costs are given separately for: (1) covering all currently dry areas of the pile except the berm area; and (2) for covering the entire pile (assuming that currently wet areas of the pile have had time to dry) except the berm area. In the draft economic analysis estimates were also made for interim covers on berm areas. These estimates were eliminated here because the technical feasibility of this option is open to question. In addition, interim cover for evaporation ponds has also been eliminated from the final rule due to the economic inefficiency of applying this cover and removing it later when the ponds are excavated.

6.2 BENEFITS OF ALTERNATIVE WORK PRACTICES

6.2.1 New Model Tailings Impoundments

The radon-222 emissions from model new tailings impoundments are summarized in Exhibit 6-6. Operational emissions are given on a yearly basis for the 15 years active period, the 5 year dry out period, and as an average for the entire 20 year period. Post-operational emissions are also given on a yearly basis for each pile type. These yearly emissions are then summed to provide estimates of total emissions for each pile type over 20 years, 40 years and 60 years. Exhibit 6-7 provides the total number of fatal cancers which will occur over 20, 40 and 60 years as a result of the radon-222 emissions estimated in Exhibit 6-6. Exhibit 6-7 also provides the number of fatal cancers which will be avoided over 20, 40 and 60 years as a result of using a disposal strategy other than a single cell impoundment with no required final cover.

6.2.2 Existing Tailings Impoundments

The radon-222 emission levels given various work practices were estimated for each existing tailings pile and are presented on an annual basis in Exhibit 6-8. The resulting estimated fatal cancers per year which will result from these emissions were also calculated and are presented in Exhibit 6-9. Emissions and fatal cancers are provided for current conditions, assuming that the piles have had time to dry, assuming that a one meter dirt cover has been placed on all currently dry portions of the piles except

EXHIBIT 6-5:

COST OF INTERIM COVER OPTION ON EXISTING PILES

(Millions of 1985 Dollars)

State	Company Name	Pile Name	Cost of Interim Cover: Currently Dry Areas (Except Berm)	Cost of Interim Cover: All Areas[a] (Except Berm)
Colorado	Cotter Corp.	Primary	0.11	2.38
		Secondary	0.85	0.88
	Umetco	Pile 1&2	0.48	0.59
		Pile 3	0.34	0.42
		Sludge Pile	0.54	0.57
		Evap. Pond	0.0	0.0
New Mexico	Sohio	L-Bar	0.82	3.17
	United Nuclear	Churchrock	1.10	3.46
	Anaconda	Bluewater 1	6.77	6.71
		Bluewater 2	1.33	1.33
		Bluewater 3	0.68	0.68
		Evap. Ponds	0.0	0.0
	Kerr-McGee	Quivira 1	4.33	6.54
		Quivira 2a	1.27	2.55
		Quivira 2b	0.59	0.68
		Quivira 2c	0.62	0.74
		Evap. Ponds	0.0	0.0
	Homestake	Homestake 1	0.45	3.17
		Homestake 2	1.02	1.25
Texas	Chevron	Panna Maria	1.02	3.51
Utah	Umetco	White Mesa	0.96	1.36
		White Mesa	1.27	1.72
		White Mesa	0.40	1.50
	Rio Algom	Rio 1	1.08	1.25
		Rio 2	0.42	0.91
	Atlas	Moab	1.13	2.75
	Plateau Res.	Shootaring	0.03	0.20
Washington	Dawn Mining	Ford 1,2,3	2.69	2.69
		Ford 4	0.31	0.79
	Western Nuclear	Sherwood	1.98	2.66
		Evap. Pond	0.0	0.0
Wyoming	Pathfiinder	Gas Hills 1	3.37	3.51
		Gas Hills 2	1.13	1.53
		Gas Hills 3	0.06	0.62
		Gas Hills 4	0.31	2.52
	Western Nuclear	Split Rock	1.22	4.42
	Umetco	E. Gas Hills	4.28	4.28
		A-9 Pit	0.40	0.71
		Leach Pad	0.62	0.62
		Evap. Ponds	0.0	0.0
	Rock Mt. Energy	Bear Creek	1.50	3.43
	Pathfinder	Shirely Basin	1.70	7.39
	Minerals Exp.	Sweetwater	0.20	1.05
U.S. Total[b]			47.38	84.60

a/ Assumes the wet areas of the piles have had time to dry out.

b/ Totals may not agree due to rounding.

EXHIBIT 6-6

SUMMARY OF RADON-222 EMISSIONS FROM MODEL NEW TAILINGS IMPOUNDMENTS

	Operational Emissions (kCi/y)[a]			Post-Operational Emissions (kCi/y)[a]		Total Emissions (kCi)		
Alternative	Active Years 0-15	Dry Out Years 16-20	Average	Uncovered	With Final Cover[b]	20 years	40 years	60 years
1. Single cell Impoundment[c]	0.8	2.5	1.2	NA	0.3	24	30	36
2. Phased disposal	NA	NA	0.7[d]	NA	0.3	14	20	26
3. Continuous disposal	NA	NA	0.5[e]	NA	0.3	9	15	21
4. No action (single cell without cover)	0.8	2.5	1.2	4.2	NA	24	110	190

NA - not applicable

a/ Emission estimates based on a flux of 1 pCi/m^2-sec per pCi radium-226 per g tailings and a radium-226 concentration of 280 pCi/g

b/ Final cover to meet 20 pCi/m^2-sec standard

c/ Assumes 20% of the impoundment area is dry beach during the 15-year active life, remainder is water covered.

d/ Based on 20-year life, 15-year active, and 5-year dry out.

e/ Based on 15-year life

EXHIBIT 6-7:

SUMMARY OF ESTIMATED FATAL CANCERS AND FATAL CANCERS AVOIDED DUE TO MODEL NEW TAILINGS IMPOUNDMENTS [a]

		Fatal Cancers			Fatal Cancers Avoided[b]		
		20 Years	40 Years	60 Years	20 Years	40 Years	60 Years
No Action —	Single Cell Impoundment (without final cover)	0.5	2	4	—	—	—
Alternative 1 —	Single Cell Impoundment (with final cover after 20 years)	0.5	0.6	0.7	0	2	3
Alternative 2 —	Phased Disposal	0.3	0.4	0.5	0.2	2	3
Alternative 3 —	Continuous Disposal	0.2	0.3	0.5	0.3	2	3

[a] Differences may not add due to rounding.

[b] Fatal cancers avoided by choosing alternative diposal technology over the conventional single cell impoundment.

EXHIBIT 6-8:

SUMMARY OF RADON-222 EMISSIONS FROM EXISTING TAILINGS IMPOUNDMENTS GIVEN VARIOUS COVERS

State	Company Name	Pile Name	RADON-222 Emissions (kci/y): 1985 Conditions	All Areas Dry Without Covers	Interim Cover[1] On Currently Dry Areas (Except Berms)	Interim Cover[2] On All Areas (Except Berms)	Final[3] Cover
Colorado	Cotter Corp	Primary	0.4	8.4	0.2	3.2	0.2
		Secondary	3.0	3.1	1.1	1.2	0.1
	Umetco	Pile 1&2	3.8	4.0	3.2	3.2	0.2
		Pile 3	1.8	2.0	1.3	1.4	0.1
		Sludge Pile	1.2	1.2	0.4	0.5	0.1
		Evap. Pond	0.9	1.0	0.9	1.0	—
New Mexico	Sohio	L-Bar	2.9	8.2	1.7	3.7	0.3
	United Nuclear	Churchrock	2.4	5.5	1.3	2.5	0.4
	Anaconda	Bluewater 1	18.9	18.9	7.3	7.3	0.6
		Bluewater 2	3.7	3.7	1.4	1.4	0.1
		Bluewater 3	1.9	1.9	0.7	0.7	0.1
		Evap. Ponds	3.8	12.8	3.8	12.8	—
	Kerr-McGee	Quivira 1	15.1	21.3	7.7	10.1	0.7
		Quivira 2a	4.7	8.3	2.5	3.9	0.3
		Quivira 2b	2.0	2.2	1.0	1.0	0.1
		Quivira 2c	2.1	2.4	1.0	1.1	0.1
		Evap. Ponds	7.5	29.4	7.5	29.4	—
	Homestake	Homestake 1	5.4	10.1	4.9	6.7	0.5
		Homestake 2	1.8	2.2	0.7	0.8	0.1
Texas	Chevron	Panna Maria	0.9	3.1	0.3	1.2	0.3
Utah	Umetco	White Mesa	1.5	2.1	0.6	0.8	0.1
		White Mesa	2.0	2.7	0.8	1.0	0.2
		White Mesa	0.6	2.4	0.2	0.9	0.1
	Rio Algom	Rio 1	2.7	3.1	1.0	1.2	0.1
		Rio 2	1.1	2.3	0.4	0.9	0.1
	Atlas	Moab	6.2	10.1	4.5	6.0	0.4
	Plateau Res.	Shootaring	0.1	0.2	0.1	0.1	0.0
Washington	Dawn Mining	Ford 1,2,3	2.9	2.9	1.2	1.2	0.2
		Ford 4	0.3	0.9	0.4	0.4	0.1
	Western Nuclear	Sherwood	1.8	2.4	0.7	0.9	0.2
		Evap. Ponds	0.0	0.4	0.0	0.4	—
Wyoming	Pathfinder	Gas Hills 1	6.4	6.6	2.4	2.5	0.3
		Gas Hills 2	2.1	2.9	0.8	1.1	0.1
		Gas Hills 3	0.1	1.2	0.0	0.5	0.1
		Gas Hills 4	0.6	4.8	0.2	1.8	0.2
	Western Nuclear	Split Rock	2.4	8.6	0.9	3.3	0.4
	Umetco	E. Gas Hills	6.0	6.0	2.3	2.3	0.4
		A-9 Pit	0.6	1.0	0.2	0.4	0.1
		Leach Pad	0.9	0.9	0.3	0.3	0.1
		Evap. Ponds	0.0	0.8	0.0	0.8	—
	Rock Mt. Energy	Bear Creek	2.8	6.5	1.1	2.5	0.3
	Pathfinder	Shirley Basin	4.1	18.0	1.6	6.9	0.7
	Minerals Exp.	Sweetwater	0.2	1.3	0.1	0.5	0.1
ANNUAL U.S. TOTAL[4]			129.6	239.1	68.7	129.8	8.8

[1] Assumes current level of water cover and no interim cover on evaporation ponds. Evaporation ponds are assumed to remain wet (1985 conditions).

[2] Assumes the wet areas of the piles have had time to dry and no interim cover on evaporation ponds.

[3] Assumes evaporation ponds are moved to main impoundment at final disposal.

[4] Totals may not agree due to independent rounding.

EXHIBIT 6-9:

SUMMARY OF YEARLY ESTIMATED FATAL CANCERS FROM EXISTING TAILINGS IMPOUNDMENTS FOR VARIOUS COVERS

State	Company Name	Pile Name	ESTIMATED FATAL CANCERS (COMMITTED CANCERS/Y) 1985 Conditions	All Areas Dry Without Covers	Interim Cover[1] On Currently Dry Areas (Except Berms)	Interim Cover[2] On All Areas (Except Berms)	Final[3] Cover
Colorado	Cotter Corp	Primary	.01	.3	.006	.1	.006
		Secondary	.09	.1	.03	.04	.003
	Umetco	Pile 1&2	.07	.07	.06	.06	.004
		Pile 3	.03	.04	.02	.03	.002
		Sludge Pile	.02	.02	.007	.009	.002
		Evap. Ponds	.02	.02	.02	.02	—
New Mexico	Sohio	L-Bar	.08	.2	.05	.1	.008
	United Nuclear	Churchrock	.05	.1	.03	.05	.008
	Anaconda	Bluewater 1	.4	.4	.2	.2	.01
		Bluewater 2	.09	.09	.03	.03	.002
		Bluewater 3	.04	.04	.02	.02	.002
		Evap. Ponds	.09	.3	.09	.3	—
	Kerr-McGee	Quivira 1	.3	.4	.1	.2	.01
		Quivira 2a	.08	.1	.05	.07	.005
		Quivira 2b	.04	.04	.02	.02	.002
		Quivira 2c	.04	.04	.02	.02	.002
		Evap. Ponds	.1	.5	.1	.5	—
	Homestake	Homestake 1	.1	.3	.1	.2	.01
		Homestake 2	.05	.06	.02	.02	.003
Texas	Chevron	Panna Maria	.04	.1	.01	.05	.01
Utah	Umetco	White Mesa	.02	.03	.008	.01	.001
		White Mesa	.03	.04	.01	.01	.003
		White Mesa	.008	.03	.003	.01	.001
	Rio Algom	Rio 1	.04	.04	.01	.02	.001
		Rio 2	.02	.03	.006	.01	.001
	Atlas	Moab	.1	.2	.08	.1	.007
	Plateau Res.	Shootaring	.001	.002	.001	.001	.000
Washington	Dawn Mining	Ford 1,2,3	.06	.06	.03	.03	.004
		Ford 4	.008	.02	.01	.01	.002
	Western Nuclear	Sherwood	.03	.05	.01	.02	.004
		Evap. Ponds	.0	.007	.0	.007	—
Wyoming	Pathfinder	Gas Hills 1	.08	.08	.03	.03	.004
		Gas Hills 2	.03	.04	.01	.01	.001
		Gas Hills 3	.001	.02	.0	.006	.001
		Gas Hills 4	.007	.06	.002	.02	.002
	Western Nuclear	Split Rock	.03	.1	.01	.04	.005
	Umetco	E. Gas Hills	.07	.07	.03	.03	.005
		A-9 Pit	.007	.01	.002	.005	.001
		Leach Pad	.01	.01	.004	.004	.001
		Evap. Ponds	.0	.01	.0	.01	—
	Rock Mt. Energy	Bear Creek	.04	.09	.02	.03	.004
	Pathfinder	Shirley Basin	.05	.2	.02	.09	.009
	Minerals Exp.	Sweetwater	.002	.02	.001	.006	.001
ANNUAL U.S. TOTAL[4]			2.36	4.44	1.304	2.48	0.15

[1] Assumes current level of water cover and no interim cover on evaporation ponds. Evaporation ponds are assumed to remain wet (1985 conditions).

[2] Assumes the wet areas of the piles have had time to dry and no interim cover on evaporation ponds.

[3] Assumes evaporation ponds are moved to main impoundment at final disposal.

[4] Totals may not agree due to independent rounding.

tailing sand berms (without drying), assuming that a one meter interim cover has been placed over the entire pile except tailing sand berms (i.e., the wet areas of the piles have had time to dry), and assuming that the piles have received a final cover of depth required to reduce emission to 20 pCi/m^2-sec.

It should be noted that when interim cover is applied to the dry portions of an impoundment with wet or ponded areas, emissions (and fatal cancers) will rise as the currently wet areas dry. The emissions (or fatal cancers) which will be incurred after the wet areas have dried may be calculated by subtracting emissions (or fatal cancers) under current conditions from these under dry conditions and adding the result to the emissions (or total cancers) previously calculated for interim covers on dry areas only.

6.3 ESTIMATED TOTAL SOCIAL BENEFITS AND COSTS OF ALTERNATIVE WORK PRACTICES

The work practices for disposal of uranium mill tailings described in the previous chapter each act to reduce the future incidence rate of fatal lung cancers in the local regions surrounding today's mill sites, in the local regions surrounding future mill sites, and in a very large portion of the nation lying "downwind" of these mill sites due to the four day half-life of radon-222. The economic and financial impacts of these recommendations vary significantly, depending on the year selected for conversion to the recommended practices, since the industry currently has a large amount of unused tailings disposal capacity remaining in impoundments which do not comply with the new requirements. Adoption of the recommended work practices will also result in a shift in the timing of major expenditures required for excavation of new impoundments and for the final stabilization of both new and existing impoundments. The disparate patterns of costs and avoided fatalities resulting from each possible choice of recommended work practice and year of introduction make it difficult to compare the possible regulatory alternatives without the use of a detailed site-specific analysis.

For this analysis, the small number (43) of existing impoundments at currently licensed mills permitted analysis of the impact of the possible regulatory alternatives at existing mills using site-by-site data on estimated health effects and unit costs presented above in Exhibits 6-4, 6-5, 6-8 and 6-9. For future production at new mill sites, costs and emissions for the model mill and impoundment discussed in the Background Information Document (EPA 86, References, Chapter 3) were utilized. These data were presented in Exhibits 6-1 through 6-3, 6-6 and 6-7. In the baseline projections to 2085 presented in Chapter 4, 85 model new mills and 85 impoundments are expected to be constructed between the years 2000 and 2085 under the low domestic uranium production scenario. As noted in Section 4.1, the alternative case of high domestic production is also a reasonable forecast. This assumption is addressed in the sensitivity analysis in Chapter 8. Production requirements from now to 2000 are assumed to be met with production from currently existing mills, all of which are assumed to cease operation by the end of this century. In this discussion total costs and benefits estimates are presented separately for existing mills and impoundments and for the 85 projected new impoundments at future mills.

As noted in the Introduction to this analysis of the final rulemaking, several changes in the technical description of the interim cover alternative have been made in response to comments received during the public comment period which followed the publication of the Draft Economic Analysis. These changes have been incorporated into Sections 6.3.3 and 6.3.4, which discuss the cost and benefits at existing mills.

6.3.1 Total Cost Estimates: Future Mills

The DOE low domestic uranium production forecast led to the projection that 85 new mills and model new impoundments would be constructed between the years 2000 and 2085. The estimated total cost and present value cost of the alternative work practices at the future model mill were presented in Exhibits 6-1 through 6-3. For this analysis cost data for the entirely below-grade impoundment is used. In the sensitivity analysis presented in Chapter 8, total costs of the alternative wo-k practices for the partially below-grade impoundments are examined.

The low production forecast, combined with the assumption that all existing mills cease operations by the year 2000, leads to the projection that 11 model new mills are brought on-line beginning in the year 2001. Small growth in demand thereafter implies the addition of 2 or 3 new mills in each five year period through the year 2015. In the period beginning with 2016, the original 11 model new mills are retired, in accordance with the assumed 15-year life for the model future mill. In this period, 11 additional model new mills must be constructed to replace these retirements, and again an additional 2 or 3 mills are required to meet the small projected growth in demand. The model for future mills therefore exhibits a 15-year periodicity which is somewhat artificial, resulting from the assumption that all existing mills are retired by the year 2000. This periodicity will be evident in all results presented in this subsection.

The estimated post-2000 life-cycle cost estimates developed for the alternative work practices at the 85 future impoundments are presented in Exhibits 6-10A, 6-10B, and 6-10C. In these exhibits, total cost by period and cumulative costs are shown for the baseline single-cell impoundment at the future mills, with a 40-year dry standby period. Adoption of the "straw man" assumption that the baseline impoundment will not achieve final stabilization until 40 years after drying is based on a desire to estimate the relative magnitude of costs and benefits for all alternatives. Assuming a shorter period before final stabilization, e.g., 20 years, results in lower cost and benefits estimates for all alternatives at both new and existing impoundments. Results derived under the 20 year baseline assumption are presented in Chapter 7.

The total additional real resource cost stream for the alternative work practices are obtained by subtracting the baseline life-cycle cost stream from the life-cycle cost stream under the alternative work practice, yielding the net additional cost of the alternative. This quantity is labeled in the exhibits as the added cost of the alternative. Present values of each cost stream are shown at the bottom of each column. The present value costs are calculated in 1985 dollars, assuming that all costs in a five-year period are expended at the beginning of the period. The added present value cost of each alternative is small, due to the large time span between the present time and the beginning of operation of the first new model mills in the year 2000.

The total life-cycle cost of the single impoundment option, with final cover five years after filling, are identical to the costs for the baseline, which assumes the same disposal system but with cover 40 years later. Although total added costs for this alternative sum to zero over the time frame selected for analysis, the present values of the added cost stream for this alternative are positive. This reflects the lost opportunity value associated with the earlier time of final stabilization.

The costs for the phased disposal option shown in Exhibit 6-10B has total life-cycle costs which are approximately 15 percent higher than for the baseline impoundment. But a large portion of excavation costs are incurred later in time for each mill, due to the more uniform pattern of expenses for the phased disposal shown in Exhibit 6-3. This timing advantage for phased disposal reduces the difference in costs when present

EXHIBIT 6-10A:

COST OF AN ALTERNATIVE WORK PRACTICE

AT FUTURE URANIUM MILLS — COVER IN FIVE YEARS AFTER FILLING

(millions 1985 dollars)

	baseline		COVER IN 5 YEARS		added cost	
PERIOD	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE
1986-90	0	0	0	0	0	0
1991-95	0	0	0	0	0	0
1996-00	0	0	0	0	0	0
2001-05	268	268	268	268	0	0
2006-10	33	301	33	301	0	0
2011-15	33	334	33	334	0	0
2016-20	301	636	301	636	0	0
2021-25	67	702	130	765	63	63
2026-30	67	769	75	840	8	71
2031-35	334	1104	342	1183	8	79
2036-40	67	1171	138	1320	71	150
3041-45	100	1271	116	1437	16	165
2046-50	334	1606	350	1787	16	181
2051-55	100	1706	179	1966	79	260
2056-60	100	1806	116	2082	16	276
2061-65	431	2237	392	2474	-39	236
2066-70	108	2345	179	2653	71	307
2071-75	108	2454	124	2777	16	323
2076-80	439	2893	392	3168	-47	276
2081-85	116	3009	187	3355	71	347
post-2085 (*)	504	3513	158	3513	-347	0
TOTAL	3513		3513		0	
PV(1%)	1865		1969		105	
PV(5%)	341		366		26	
PV(10%)	101		104		3.5	

(*) Post-2085 costs include all remaining life-cycle costs for impoundments started before 2085 by not covered by that date. All post-2085 costs are expressed in present value in the year 2085.

EXHIBIT 6-10B:

COST OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — PHASED DISPOSAL

(millions 1985 dollars)

	baseline		PHASED DISPOSAL		added cost	
PERIOD	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE
1986-90	0	0	0	0	0	0
1991-95	0	0	0	0	0	0
1996-00	0	0	0	0	0	0
2001-05	268	268	104	104	-164	-164
2006-10	33	301	129	232	95	-69
2011-15	33	334	155	387	122	53
2016-20	301	636	171	558	-130	-77
2021-25	67	702	187	745	120	43
2026-30	67	769	203	948	136	179
2031-35	334	1104	219	1167	-116	63
2036-40	67	1171	222	1388	155	218
3041-45	100	1271	236	1625	136	354
2046-50	334	1606	238	1862	-97	257
2051-55	100	1706	252	2114	152	409
2056-60	100	1806	254	2368	153	562
2061-65	431	2237	268	2636	-163	399
2066-70	108	2345	270	2906	161	560
2071-75	108	2454	271	3177	163	723
2076-80	439	2893	271	3448	-168	555
2081-85	116	3009	271	3719	155	710
post-2085 (*)	504	3513	347	4066	-157	553
TOTAL	3513		4066		553	
PV(1%)	1865		2218		353	
PV(5%)	341		363		22	
PV(10%)	101		87		-13	

(*) Post-2085 costs include all remaining life-cycle costs for impoundments started before 2085 by not covered by that date. All post-2085 costs are expressed in present value in the year 2085.

values are calculated. At a 5 percent discount rate, life-cycle costs for phased disposal are approximately equal to those for the baseline. At a 10 percent discount rate, the present value cost of phased disposal is less than that for the baseline.

The total life-cycle costs for the continuous disposal option shown in Exhibit 6-10C are higher than for the baseline impoundment. Continuous disposal also has a timing advantage in the delayed expenditure of funds for excavation costs. Hence the cost difference between continuous disposal and the baseline method also decreases at higher discount rates. At a 1 percent discount the total life-cycle cost streams differ by 37 percent; at a 5 percent discount the difference is 28 percent; and at 10 percent, only 8 percent.

Graphs of the total added cost streams for each alternative are shown in Exhibits 6-11A, 6-11B, and 6-11C. These cost streams exhibit the 15 year periodicity in the pattern of positive added costs and negative added costs shown in each graph. As noted above, the periodicity is somewhat artificial. However the graphs clearly show that large cost savings resulting from delayed excavation costs are followed by positive added costs later during the life-cycle of each new mill. Similar periodicity is evident in the cumulative cost graphs.

The present values of the estimated added life-cycle cost streams for each alternative work practice at future uranium mills are summarized in Exhibit 6-12. In this exhibit the present value cost at a 5 percent and 10 percent discount rate for the baseline disposal method are compared to the present value cost of each alternative. The added cost for each alternative and the percent increase in present value cost are also presented.

6.3.2 Total Benefits Estimates: Future Mills

The estimated benefits of each alternative work practice option at existing mill sites are calculated using site-specific health-effects factors computed using EPA-AIRDOS, based on the site-specific emissions estimates and local populations. This procedure is documented in the Background Information Document (EPA 86, References, Chapter 3) and is summarized in Section 6.2 above. The benefit estimates for existing mills are discussed at the end of this section. For future mills, the location of future impoundments with respect to local populations surrounding the sites are not currently

EXHIBIT 6-10C:

COST OF AN ALTERNATIVE WORK PRACTICE

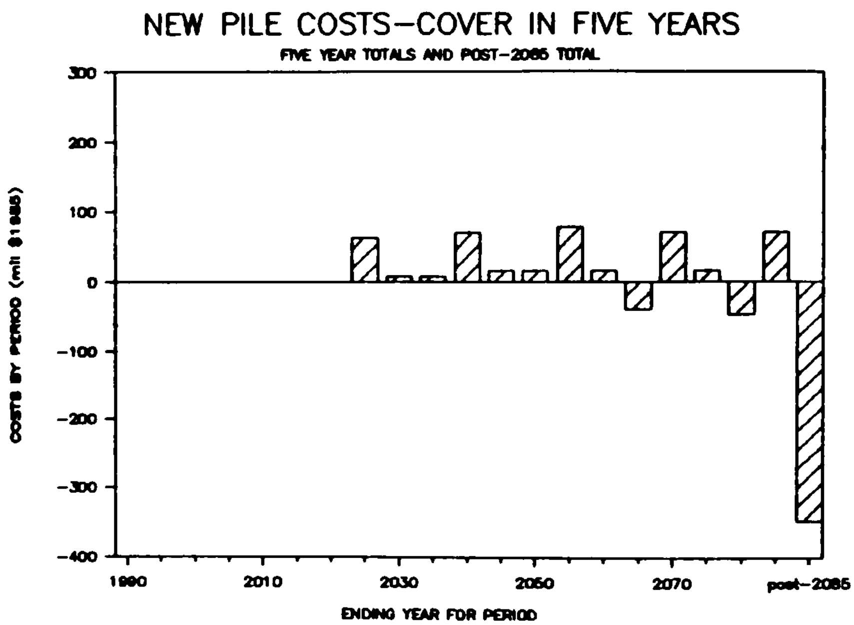
AT FUTURE URANIUM MILLS — CONTINUOUS DISPOSAL

(millions 1985 dollars)

	baseline		CONTINUOUS DISPOSAL		added cost	
PERIOD	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE
1986-90	0	0	0	0	0	0
1991-95	0	0	0	0	0	0
1996-00	0	0	0	0	0	0
2001-05	268	268	144	144	-123	-123
2006-10	33	301	163	307	129	6
2011-15	33	334	181	488	147	153
2016-20	301	636	199	686	-102	51
2021-25	67	702	217	903	150	200
2026-30	67	769	235	1138	168	368
2031-35	334	1104	253	1390	-82	287
2036-40	67	1171	253	1643	186	473
3041-45	100	1271	271	1914	171	643
2046-50	334	1606	271	2185	-64	579
2051-55	100	1706	289	2474	189	768
2056-60	100	1806	289	2763	189	957
2061-65	431	2237	307	3070	-124	833
2066-70	108	2345	307	3377	199	1031
2071-75	108	2454	307	3684	199	1230
2076-80	439	2893	307	3991	-132	1098
2081-85	116	3009	307	4298	191	1289
post-2085 (*)	504	3513	307	4605	-197	1092
TOTAL	3513		4605		1092	
PV(1%)	1865		2546		681	
PV(5%)	341		435		95	
PV(10%)	101		109		8.3	

(*) Post-2085 costs include all remaining life-cycle costs for impoundments started before 2085 by not covered by that date. All post-2085 costs are expressed in present value in the year 2085.

EXHIBIT 6-11A:
GRAPHS OF ADDED COST AND CUMULATIVE ADDED COST OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — COVER IN FIVE YEARS AFTER FILLING



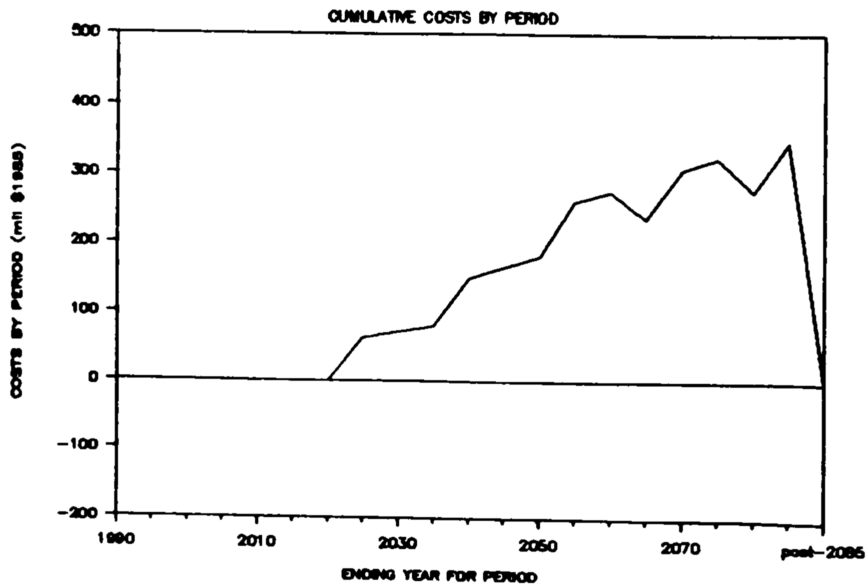
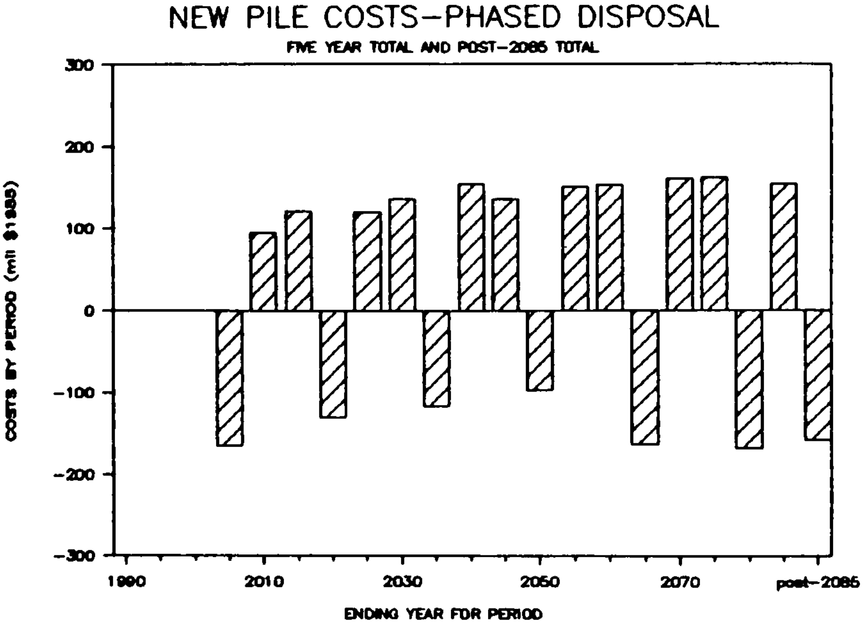


EXHIBIT 6-11B:
GRAPHS OF ADDED COST AND CUMULATIVE ADDED COST OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — PHASED DISPOSAL



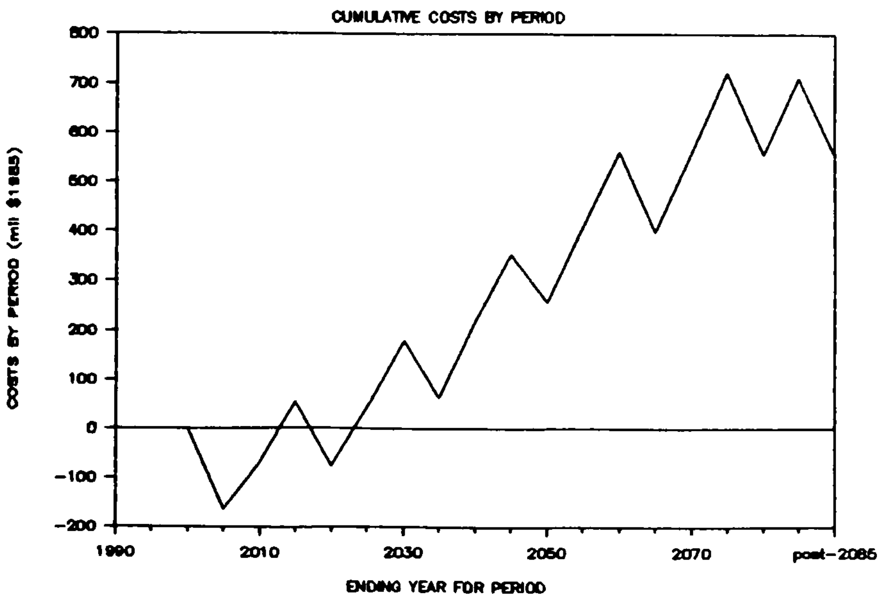
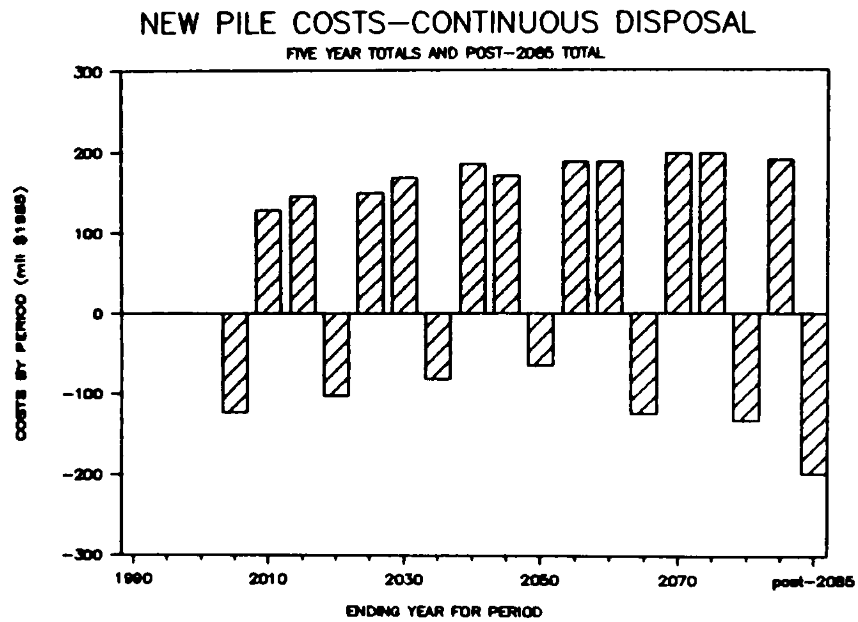


EXHIBIT 6-11C:

GRAPHS OF ADDED COST AND CUMULATIVE ADDED COST OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS -- CONTINUOUS DISPOSAL



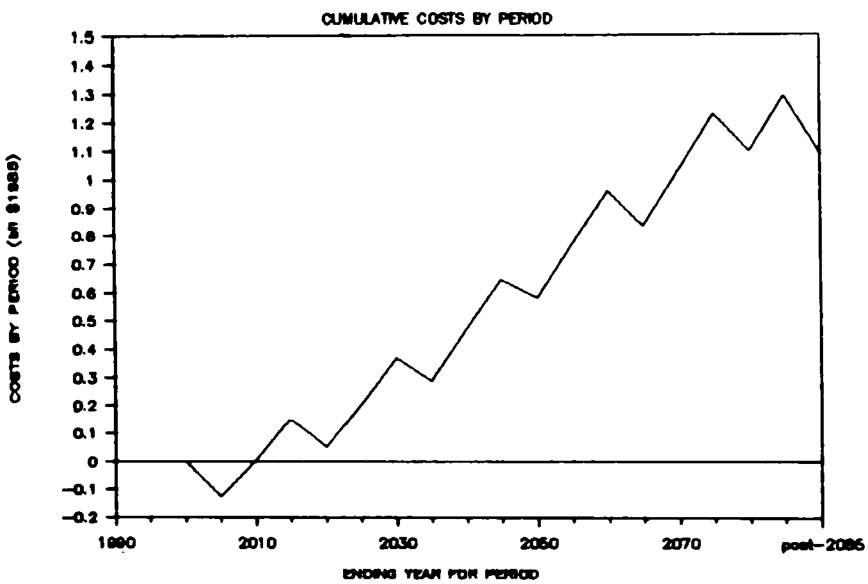


EXHIBIT 6-12:

PRESENT VALUE COST OF ALTERNATIVE WORK PRACTICES AT FUTURE URANIUM MILLS

(millions of 1985 dollars)

	5 Percent Discount Rate		10 Percent Discount Rate	
Alternative Work Practice For New Impoundments	Cost of Alternative	Added Cost (%)	Cost of Alternative	Added Cost (%)
1. Baseline impoundments covered in 5 years	366	26 (7%)	104	3.5 (3%)
2. Phased disposal	363	22 (6%)	87	-13 (-13%)
3. Continuous disposal	435	95 (28%)	109	8.3 (9%)
Baseline impoundment covered in 40 years	341	---	101	---

known. For this analysis, health effects estimates were generated for the 0-5 kilometer local area and the 5-80 kilometers local region by using the average number of health effects per curie released at all existing mill sites for each respective region. This procedure is based on the assumption that future mills will be located in rural and remote areas as are the majority of today's existing mill sites. National health effects were estimated using the same procedure as for existing mills, also based on an average number of health effects per curie released. The above assumptions lead to the following health-effect factors for new mills:

- 0-5 Km: 8.26×10^{-4} fatal lung cancers per kilocurie per year,
- 5-80 Km: 6.13×10^{-3} fatal lung cancers per kilocurie per year, and
- Rest of Nation: 1.20×10^{-2} fatal lung cancers per kilocurie per year.

Estimated benefits for the alternative work practices at the 85 new model mills projected to be on-line in the years 2000 to 2085 are presented in Exhibits 6-13A, 6-13B, and 6-13C. In these exhibits, baseline fatal lung cancers and avoided lung cancers for each alternative are shown for the local, regional and national regions and in total for each of the five-year periods. Total health effects over the 85 year period are listed at the bottom of each column. The benefits and cumulative benefits at future mill sites are graphed for each alternative in Exhibits 6-14A, 6-14B, and 6-14C.

A summary of Exhibits 6-13 (A through C) is contained in Exhibit 6-15. Examination of this exhibit shows that all three alternative new impoundment work practices result in substantial benefits when compared to the baseline. The percent of avoided fatalities for each region is identical, due to the use of the health-effects-per-Curie-released factors discussed above. For each alternative, the percent of avoided baseline fatal cancers is between 80 percent and 90 percent.

6.3.3 Total Cost Estimates: Existing Mills

Estimates of the total cost of the alternatives at existing licensed mill sites are derived by comparing the baseline disposal cost stream with the cost stream required for disposal under each alternative. The additional real resource cost resulting from each alternative is obtained by subtracting baseline cost from the cost of the alternative in

EXHIBIT 6-13A:

BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — COVER IN FIVE YEARS AFTER FILLING

(committed fatal cancers)

	baseline				Avoided Fatalities: COVER IN 5 YEARS			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991-95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996-00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001-05	0.0	0.2	0.4	0.6	0.0	0.0	0.0	0.0
2006-10	0.0	0.2	0.4	0.7	0.0	0.0	0.0	0.0
2011-15	0.0	0.2	0.5	0.8	0.0	0.0	0.0	0.0
2016-20	0.1	0.9	1.7	2.7	0.0	0.0	0.0	0.0
2021-25	0.2	1.4	2.7	4.3	0.1	1.0	1.9	3.0
2026-30	0.2	1.6	3.0	4.8	0.1	1.1	2.1	3.3
2031-35	0.3	2.3	4.5	7.2	0.2	1.2	2.3	3.7
2036-40	0.4	2.9	5.8	9.1	0.3	2.3	4.4	7.0
2041-45	0.4	3.2	6.3	10.0	0.3	2.5	4.9	7.8
2046-50	0.6	4.1	8.0	12.7	0.4	2.7	5.4	8.5
2051-55	0.6	4.8	9.4	14.8	0.5	3.9	7.7	12.2
2056-60	0.7	5.1	10.0	15.9	0.6	4.2	8.2	12.9
2061-65	0.7	5.1	10.0	15.8	0.5	3.6	7.0	11.1
2066-70	0.8	5.7	11.3	17.8	0.6	4.7	9.1	14.4
2071-75	0.8	6.0	11.8	18.6	0.7	4.9	9.6	15.2
2076-80	0.8	5.9	11.6	18.4	0.6	4.2	8.2	12.9
2081-85	0.9	6.5	12.7	20.1	0.7	5.3	10.3	16.3
post-2085	6.0	44.6	87.3	137.9	5.4	39.8	77.9	123.1
TOTAL	13.6	100.8	197.6	312.0	11.0	81.2	159.1	251.3

EXHIBIT 6-13B:
BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — PHASED DISPOSAL
(committed fatal cancers)

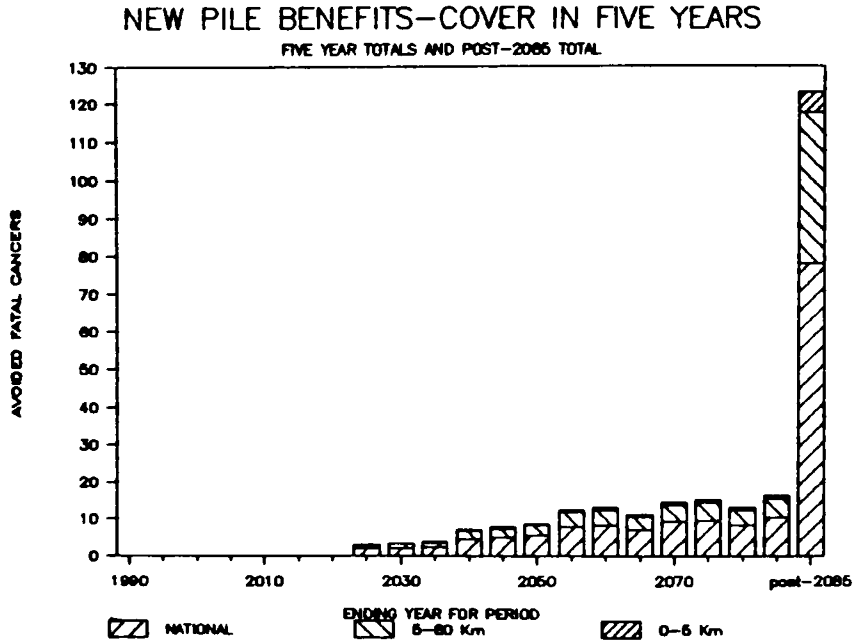
	baseline				Avoided Fatalities: PHASED DISPOSAL			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991-95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996-00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001-05	0.0	0.2	0.4	0.6	0.0	0.0	0.0	0.1
2006-10	0.0	0.2	0.4	0.7	0.0	0.0	0.1	0.1
2011-15	0.0	0.2	0.5	0.8	0.0	0.0	0.1	0.1
2016-20	0.1	0.9	1.7	2.7	0.1	0.5	0.9	1.5
2021-25	0.2	1.4	2.7	4.3	0.1	1.0	2.1	3.2
2026-30	0.2	1.6	3.0	4.8	0.2	1.2	2.3	3.6
2031-35	0.3	2.3	4.5	7.2	0.2	1.7	3.4	5.4
2036-40	0.4	2.9	5.8	9.1	0.3	2.4	4.7	7.5
2041-45	0.4	3.2	6.3	10.0	0.4	2.7	5.2	8.2
2046-50	0.6	4.1	8.0	12.7	0.5	3.3	6.6	10.3
2051-55	0.6	4.8	9.4	14.8	0.6	4.1	8.0	12.7
2056-60	0.7	5.1	10.0	15.9	0.6	4.4	8.6	13.6
2061-65	0.7	5.1	10.0	15.8	0.6	4.2	8.2	13.0
2066-70	0.8	5.7	11.3	17.8	0.7	4.9	9.6	15.1
2071-75	0.8	6.0	11.8	18.6	0.7	5.1	10.0	15.8
2076-80	0.8	5.9	11.6	18.4	0.7	4.8	9.5	15.0
2081-85	0.9	6.5	12.7	20.1	0.7	5.5	10.7	16.9
post-2085	6.0	44.6	87.3	137.9	5.5	40.8	79.9	126.1
TOTAL	13.6	100.8	197.6	312.0	11.7	86.7	169.8	268.2

EXHIBIT 6-13C:
BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — CONTINUOUS DISPOSAL
(committed fatal cancers)

	baseline				Avoided Fatalities CONTINUOUS DISPOSAL			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991-95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996-00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001-05	0.0	0.2	0.4	0.6	0.0	0.1	0.1	0.2
2006-10	0.0	0.2	0.4	0.7	0.0	0.1	0.2	0.3
2011-15	0.0	0.2	0.5	0.8	0.0	0.1	0.2	0.3
2016-20	0.1	0.9	1.7	2.7	0.1	0.6	1.3	2.0
2021-25	0.2	1.4	2.7	4.3	0.2	1.1	2.2	3.5
2026-30	0.2	1.6	3.0	4.8	0.2	1.3	2.5	3.9
2031-35	0.3	2.3	4.5	7.2	0.3	1.9	3.8	6.0
2036-40	0.4	2.9	5.8	9.1	0.3	2.5	5.0	7.8
2041-45	0.4	3.2	6.3	10.0	0.4	2.8	5.4	8.6
2046-50	0.6	4.1	8.0	12.7	0.5	3.6	7.0	11.0
2051-55	0.6	4.8	9.4	14.8	0.6	4.2	8.3	13.1
2056-60	0.7	5.1	10.0	15.9	0.6	4.5	8.9	14.0
2061-65	0.7	5.1	10.0	15.8	0.6	4.4	8.6	13.7
2066-70	0.8	5.7	11.3	17.8	0.7	5.0	9.8	15.5
2071-75	0.8	6.0	11.8	18.6	0.7	5.3	10.3	16.3
2076-80	0.8	5.9	11.6	18.4	0.7	5.1	9.9	15.7
2081-85	0.9	6.5	12.7	20.1	0.8	5.6	11.0	17.4
post-2085	6.0	44.6	87.3	137.9	5.5	41.1	80.5	127.1
TOTAL	13.6	100.8	197.6	312.0	12.1	89.3	174.9	276.3

EXHIBIT 6-14A:

GRAPHS OF BENEFITS AND CUMULATIVE BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — COVER IN FIVE YEARS AFTER FILLING



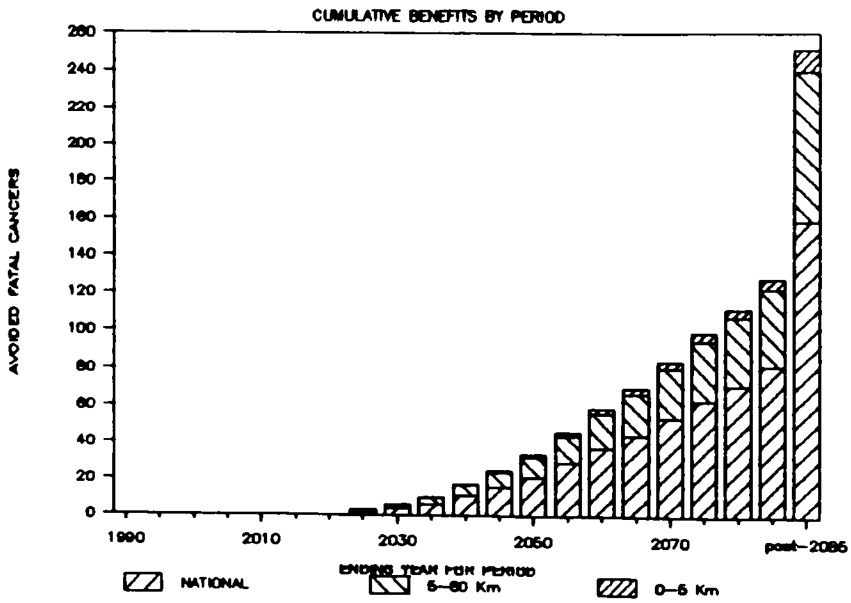
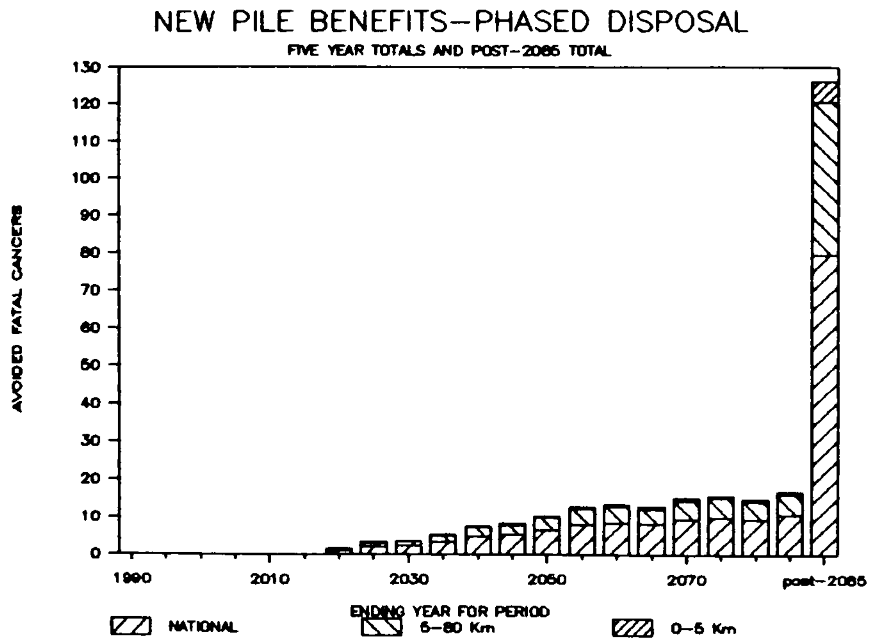


EXHIBIT 6-14B:

GRAPHS OF BENEFITS AND CUMULATIVE BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — PHASED DISPOSAL



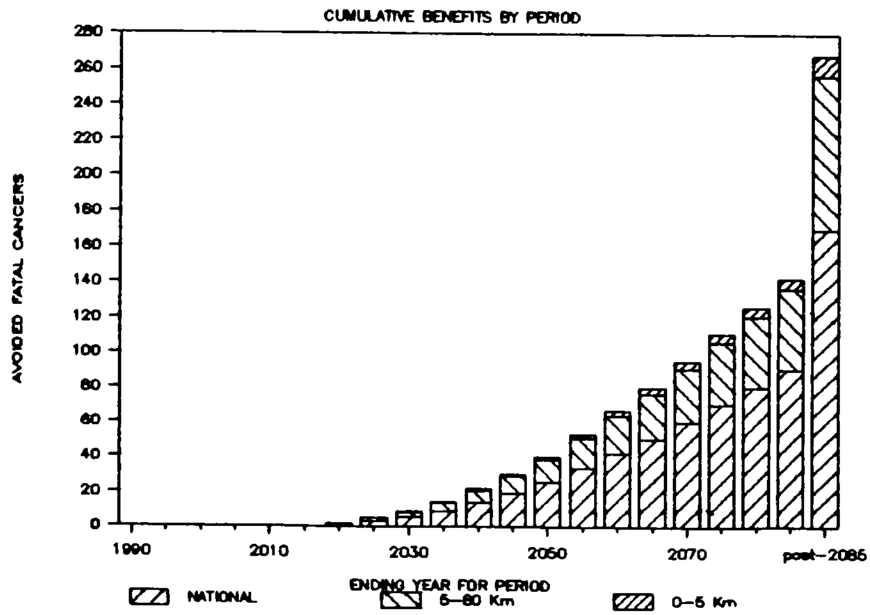
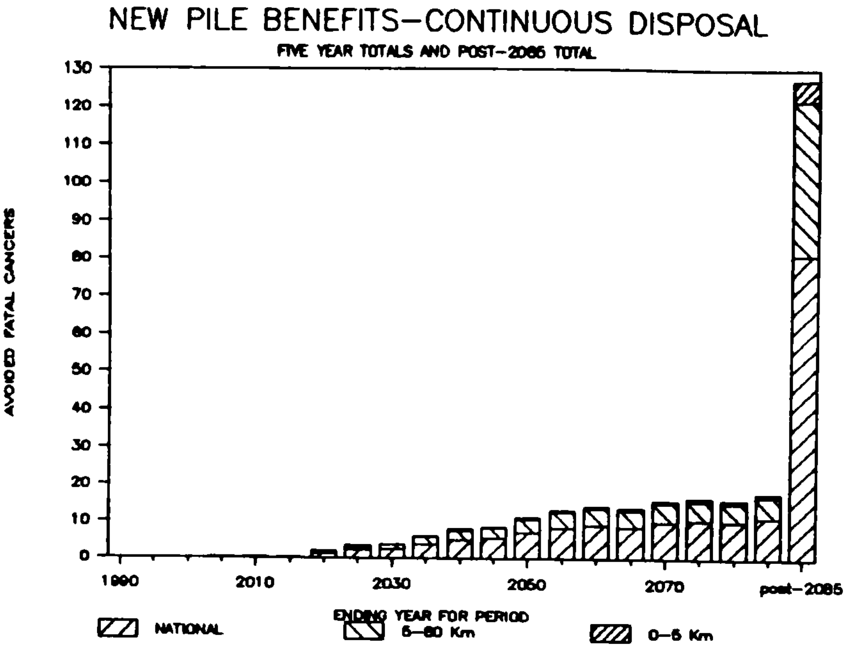


EXHIBIT 6-14C:

GRAPHS OF BENEFITS AND CUMULATIVE BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — CONTINUOUS DISPOSAL



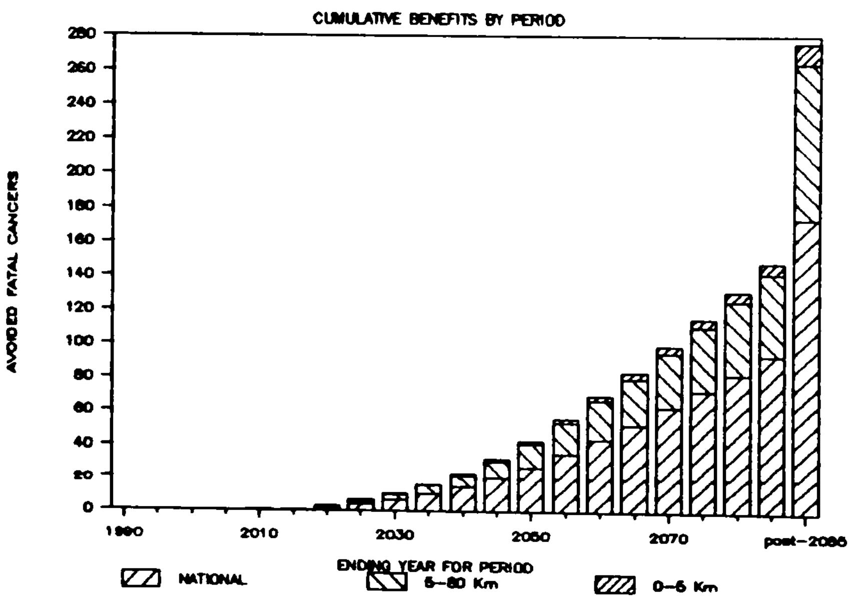


EXHIBIT 6-15:

SUMMARY OF BENEFITS OF ALTERNATIVE WORK PRACTICES AT FUTURE URANIUM MILLS

	0-5 Km			5-80 Km			Rest of Nation			Total		
Alternative	Baseline Fatalities	Avoided Fatalities	Percent Avoided	Baseline Fatalities	Avoided Fatalities	Percent Avoided	Baseline Fatalities	Avoided Fatalities	Percent Avoided	Baseline Fatalities	Avoided Fatalities	Percent Avoided
1. Baseline Impoundments (cover in 5 years)	13.6	11.0	81%	100.8	81.2	81%	197.6	159.1	81%	312	251.3	81%
2. Phased Disposal	13.6	11.7	86%	100.8	86.7	86%	197.6	169.8	86%	312	268.2	86%
3. Continuous Disposal	13.6	12.1	89%	100.8	89.3	89%	197.6	174.9	89%	312	276.3	89%

each time period, then taking the present value of the stream of additional costs. Three types of cost may be incurred: opportunity cost associated with moving up the time of final cover expenses, replacement costs for disposal in new impoundments, and interim cover costs to the extent these costs are not recoverable at the time of final stabilization.

For existing impoundments, construction costs are considered as sunk costs, and only the cost of final stabilization is considered. The timing of this cost will be affected by the proposed regulations, resulting in earlier final stabilization. In our model, we assume that currently existing Federal regulations will require final stabilization of existing impoundments within 5 years after the mill is required to go to new disposal methods at new impoundments.

In the low production scenario, only a limited number of mills are expected to produce between now and the year 2000. New tailings disposal capacity must be constructed at these mills if conversion to the recommended work practice is required before the year 2000. Costs of these replacement impoundments at existing mills were estimated based on cost data for the recommended work practices at the model new impoundment, as shown in Exhibit 6-3.

Revisions in the technical analysis of interim cover presented in the Draft Economic Analysis requires several changes in the methodology applied for calculating benefits and costs of the proposed control alternatives. These changes are a result of comments and concerns expressed by mill operators during the public comment period which followed the release of the draft analysis. Significant changes in assumptions made for this analysis of the final rulemaking includes:

1. No application of interim cover to the berms of impoundments;

2. No application of interim cover to evaporation ponds;

3. The requirement of a second interim cover application at 14 (33 percent) of 43 impoundments in the period 1995-2000 to re-cover tailings deposited during presumed operation in the period 1990-1995; and

4. An annual maintenance cost of 5 percent of the cost of the interim cover to preserve integrity of the cover in each period following its installation.

In addition, concern was expressed in the public comments that the 40-year baseline dry period before final cover may be inappropriately long. In this analysis of the final rulemaking, we will also include results for a 20-year baseline period. Results for a change in reference-case assumptions to a 20-year baseline dry period were presented previously in the sensitivity analysis (Section 6.4) of the Draft Economic Analysis. Results for the 20 year assumption are now presented in Chapter 7, and the sensitivity analysis of other assumptions is reported in Chapter 8. The following sections of this chapter report revised benefit and cost estimates for the interim cover (1 meter) alternative under the 40 year scenario.

Assumptions 1 through 3 above all influence the estimated benefits (avoided fatal cancers) resulting from the 1 meter interim cover alternative. Assumptions 1 and 2 combine to yield a small reduction in the scope of applicability of interim cover, and hence reduce both costs and benefits proportionately. Assumption 3 has a minor impact on benefits because the integrity of the interim cover is destroyed during the second operating and dry-out period, which lasts less than 10 years and affects only one-third of the impoundments. Assumption 4 affects only the cost estimates.

An application of the revised assumptions to the model developed for the Draft Economic Analysis produced the revised benefits estimates reported here for the interim cover alternative. The revised assumptions lead to a reduction in the estimated benefits of interim cover of approximately 33 percent. This change is due to the combined effects of the first three revised assumptions, in which evaporation ponds and berms are no longer covered and 14 impoundments go through a second period of operation.

The four revised assumptions for the 1-meter interim cover alternative all effect the cost estimates presented in the Draft Economic Analysis. Assumptions 1 and 2 reduce the cost of the alternative proportionately to the benefits, as noted above. Assumptions 3 and 4 have significant impacts on the cost estimation, while they produce little change in the benefits estimates.

The largest impacts of the revised assumptions on the cost of interim cover are due to the requirement for annual maintenance on the interim cover during the 40-year period before final cover.

Estimates of the total cost of each alternative at existing mills are presented in Exhibits 6-16A through 6-16E. The costs in the exhibit are expressed in 1985 dollars, and the total cost streams are separated into cost streams for final stabilization (cover), replacement of lost capacity, and interim cover. Baseline cost streams are presented in the left-most columns, estimated cost streams under each alternative are shown in the center columns, and the net added cost stream for the alternative in the right-most columns. The present values at the bottom of each column were calculated assuming costs are incurred at the beginning of each five year period. Graphs of the total added cost streams for each alternative at existing mills are shown in Exhibit 6-17A through 6-17E.

Examination of Exhibits 6-16A through 6-16E shows that the total added cost stream for final cover sums to zero, when no discount rate is applied. However, the present value cost of final cover is positive for all discount rates greater than zero. This unusual result stems from the fact that identical real resource costs for final cover occur in both the alternative cost stream and the baseline cost stream, with earlier payment of these costs under the alternative. As a result, the added cost stream for final cover contains balancing positive and negative entries. Costs of final cover may be referred to as a Type 2 cost of the rule. A type 2 cost requires no net additional expenditure of real resources, but the time of expenditure is affected by the alternative. The term "type 2 cost" serves to distinguish these costs from the cost streams for replacement impoundments and interim cover, which are referred to as Type 1 costs. These latter costs represent additional real resources required under the alternative which are not required in the baseline.

The present values of the type 2 cost stream for final cover measure the opportunity cost associated with earlier payment of these expenses for final cover. The opportunity cost first increases, going from a 1 percent discount rate to a 5 percent rate. The opportunity cost then decreases when the discount rate is raised to 10 percent. By comparison, the additional type 1 real resource cost required under the alternatives for

EXHIBIT 6-16A:
COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1990
(millions 1985 dollars)

	BASELINE				COVER BY 1990				ADDED COST			
ENDING YEAR	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL
1990	0	0	0	0	0	72	0	72	0	72	0	72
1995	0	0	0	0	658	72	0	730	658	72	0	730
2000	0	0	0	0	0	54	0	54	0	54	0	54
2005	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	88	0	0	88	0	0	0	0	-88	0	0	-88
2035	439	0	0	439	0	0	0	0	-439	0	0	-439
2040	7	0	0	7	0	0	0	0	-7	0	0	-7
2045	41	0	0	41	0	0	0	0	-41	0	0	-41
2050	83	0	0	83	0	0	0	0	-83	0	0	-83
2055	0	0	0	0	0	0	0	0	0	0	0	0
2060	0	0	0	0	0	0	0	0	0	0	0	0
2065	0	0	0	0	0	0	0	0	0	0	0	0
2070	0	0	0	0	0	0	0	0	0	0	0	0
2075	0	0	0	0	0	0	0	0	0	0	0	0
2080	0	0	0	0	0	0	0	0	0	0	0	0
2085	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	658	0	0	658	658	199	0	856	0	199	0	199
PV(1%)	413	0	0	413	626	190	0	816	213	190	0	403
PV(5%)	69	0	0	69	515	162	0	677	446	162	0	608
PV(10%)	9	0	0	9	408	138	0	546	400	138	0	538

EXHIBIT 6-16B:

COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1995

(millions 1985 dollars)

	BASELINE				COVER BY 1995				ADDED COST			
ENDING YEAR	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL
1990	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	72	0	72	0	72	0	72
2000	0	0	0	0	658	54	0	712	658	54	0	712
2005	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	88	0	0	88	0	0	0	0	-88	0	0	-88
2035	439	0	0	439	0	0	0	0	-439	0	0	-439
2040	7	0	0	7	0	0	0	0	-7	0	0	-7
2045	41	0	0	41	0	0	0	0	-41	0	0	-41
2050	83	0	0	83	0	0	0	0	-83	0	0	-83
2055	0	0	0	0	0	0	0	0	0	0	0	0
2060	0	0	0	0	0	0	0	0	0	0	0	0
2065	0	0	0	0	0	0	0	0	0	0	0	0
2070	0	0	0	0	0	0	0	0	0	0	0	0
2075	0	0	0	0	0	0	0	0	0	0	0	0
2080	0	0	0	0	0	0	0	0	0	0	0	0
2085	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	658	0	0	658	658	126	0	784	0	126	0	126
PV(1%)	413	0	0	413	595	118	0	713	182	118	0	300
PV(5%)	69	0	0	69	404	90	0	494	334	90	0	424
PV(10%)	9	0	0	9	254	66	0	319	245	66	0	311

EXHIBIT 6-16C:
COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2000
(millions 1985 dollars)

	baseline				2000				added cost			
PERIOD	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL
1986-90	0	0	0	0	0	0	0	0	0	0	0	0
1991-95	0	0	0	0	0	0	0	0	0	0	0	0
1996-00	0	0	0	0	0	54	0	54	0	54	0	54
2001-05	0	0	0	0	658	0	0	658	658	0	0	658
2006-10	0	0	0	0	0	0	0	0	0	0	0	0
2011-15	0	0	0	0	0	0	0	0	0	0	0	0
2016-20	0	0	0	0	0	0	0	0	0	0	0	0
2021-25	0	0	0	0	0	0	0	0	0	0	0	0
2026-30	88	0	0	88	0	0	0	0	-88	0	0	-88
2031-35	439	0	0	439	0	0	0	0	-439	0	0	-439
2036-40	7	0	0	7	0	0	0	0	-7	0	0	-7
2041-45	41	0	0	41	0	0	0	0	-41	0	0	-41
2046-50	83	0	0	83	0	0	0	0	-83	0	0	-83
2051-55	0	0	0	0	0	0	0	0	0	0	0	0
2056-60	0	0	0	0	0	0	0	0	0	0	0	0
2061-65	0	0	0	0	0	0	0	0	0	0	0	0
2066-70	0	0	0	0	0	0	0	0	0	0	0	0
2071-75	0	0	0	0	0	0	0	0	0	0	0	0
2076-80	0	0	0	0	0	0	0	0	0	0	0	0
2081-85	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	658	0	0	658	658	54	0	712	0	54	0	54
PV(1%)	413	0	0	413	566	49	0	615	153	49	0	202
PV(5%)	69	0	0	69	316	33	0	350	247	33	0	280
PV(10%)	9	0	0	9	157	21	0	178	149	21	0	170

EXHIBIT 6-16D:

COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2005

(millions 1985 dollars)

	BASELINE				COVER BY 2005				ADDED COST			
ENDING YEAR	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL
1990	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	658	0	0	658	658	0	0	658
2015	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0
2030	88	0	0	88	0	0	0	0	-88	0	0	-88
2035	439	0	0	439	0	0	0	0	-439	0	0	-439
2040	7	0	0	7	0	0	0	0	-7	0	0	-7
2045	41	0	0	41	0	0	0	0	-41	0	0	-41
2050	83	0	0	83	0	0	0	0	-83	0	0	-83
2055	0	0	0	0	0	0	0	0	0	0	0	0
2060	0	0	0	0	0	0	0	0	0	0	0	0
2065	0	0	0	0	0	0	0	0	0	0	0	0
2070	0	0	0	0	0	0	0	0	0	0	0	0
2075	0	0	0	0	0	0	0	0	0	0	0	0
2080	0	0	0	0	0	0	0	0	0	0	0	0
2085	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	658	0	0	658	658	0	0	658	0	0	0	0
PV(1%)	413	0	0	413	539	0	0	539	126	0	0	126
PV(5%)	69	0	0	69	248	0	0	248	179	0	0	179
PV(10%)	9	0	0	9	98	0	0	98	89	0	0	89

EXHIBIT 6-16E:

COST OF INTERIM COVER AT EXISTING URANIUM MILLS

(millions 1985 dollars)

	baseline				INTERIM ONLY				added cost			
PERIOD	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL
1986-90	0	0	0	0	0	0	21	21	0	0	21	21
1991-95	0	0	0	0	0	0	68	68	0	0	68	68
1996-00	0	0	0	0	0	0	32	32	0	0	32	32
2001-05	0	0	0	0	0	0	46	46	0	0	46	46
2006-10	0	0	0	0	0	0	35	35	0	0	35	35
2011-15	0	0	0	0	0	0	24	24	0	0	24	24
2016-20	0	0	0	0	0	0	24	24	0	0	24	24
2021-25	0	0	0	0	0	0	24	24	0	0	24	24
2026-30	88	0	0	88	88	0	19	107	0	0	19	19
2031-35	439	0	0	439	439	0	5	444	0	0	5	5
2036-40	7	0	0	7	7	0	5	12	0	0	5	5
2041-45	41	0	0	41	41	0	3	44	0	0	3	3
2046-50	83	0	0	83	83	0	0	83	0	0	0	0
2051-55	0	0	0	0	0	0	0	0	0	0	0	0
2056-60	0	0	0	0	0	0	0	0	0	0	0	0
2061-65	0	0	0	0	0	0	0	0	0	0	0	0
2066-70	0	0	0	0	0	0	0	0	0	0	0	0
2071-75	0	0	0	0	0	0	0	0	0	0	0	0
2076-80	0	0	0	0	0	0	0	0	0	0	0	0
2081-85	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	658	0	0	658	658	0	308	966	0	0	308	308
PV(1%)	413	0	0	413	413	0	258	671	0	0	258	258
PV(5%)	69	0	0	69	69	0	151	220	0	0	151	151
PV(10%)	9	0	0	9	9	0	97	106	0	0	97	97

EXHIBIT 6-17A:

GRAPH OF ADDITIONAL COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1990

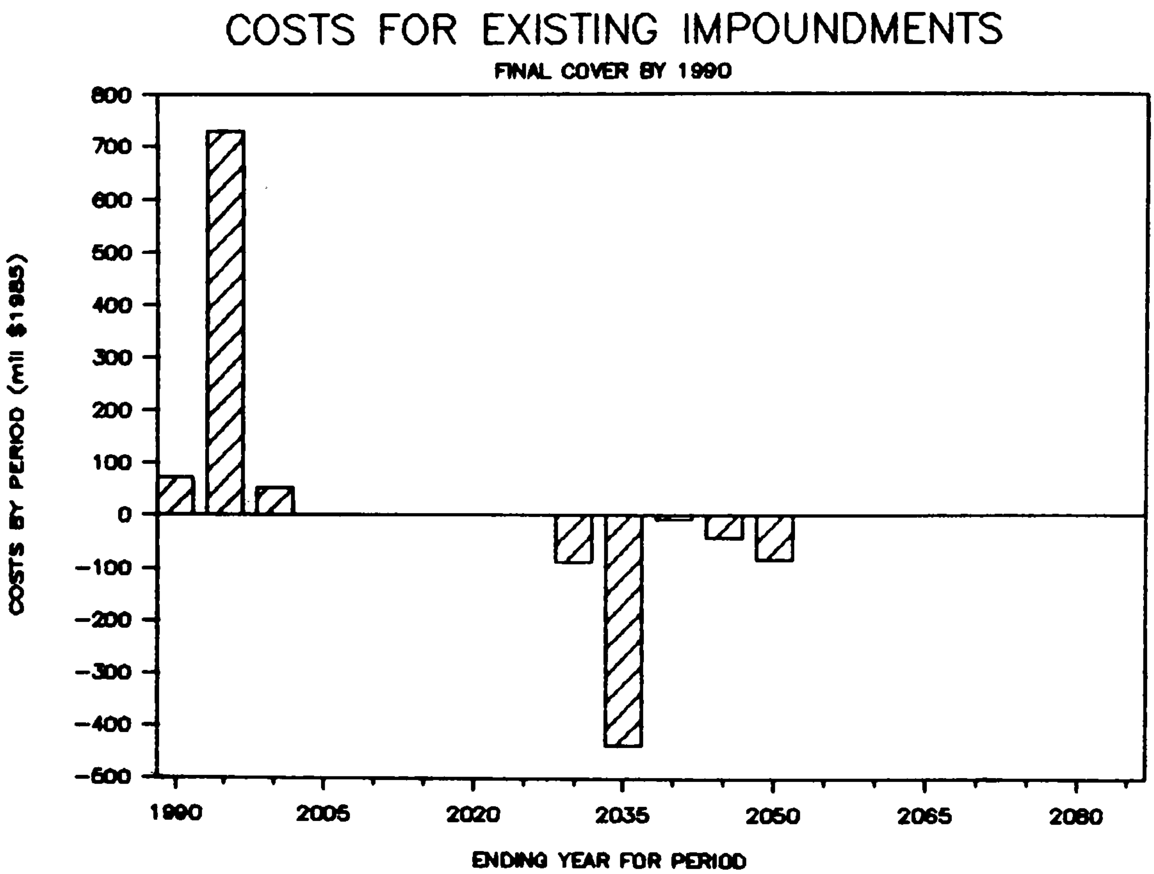


EXHIBIT 6-17B:

GRAPH OF ADDITIONAL COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1995

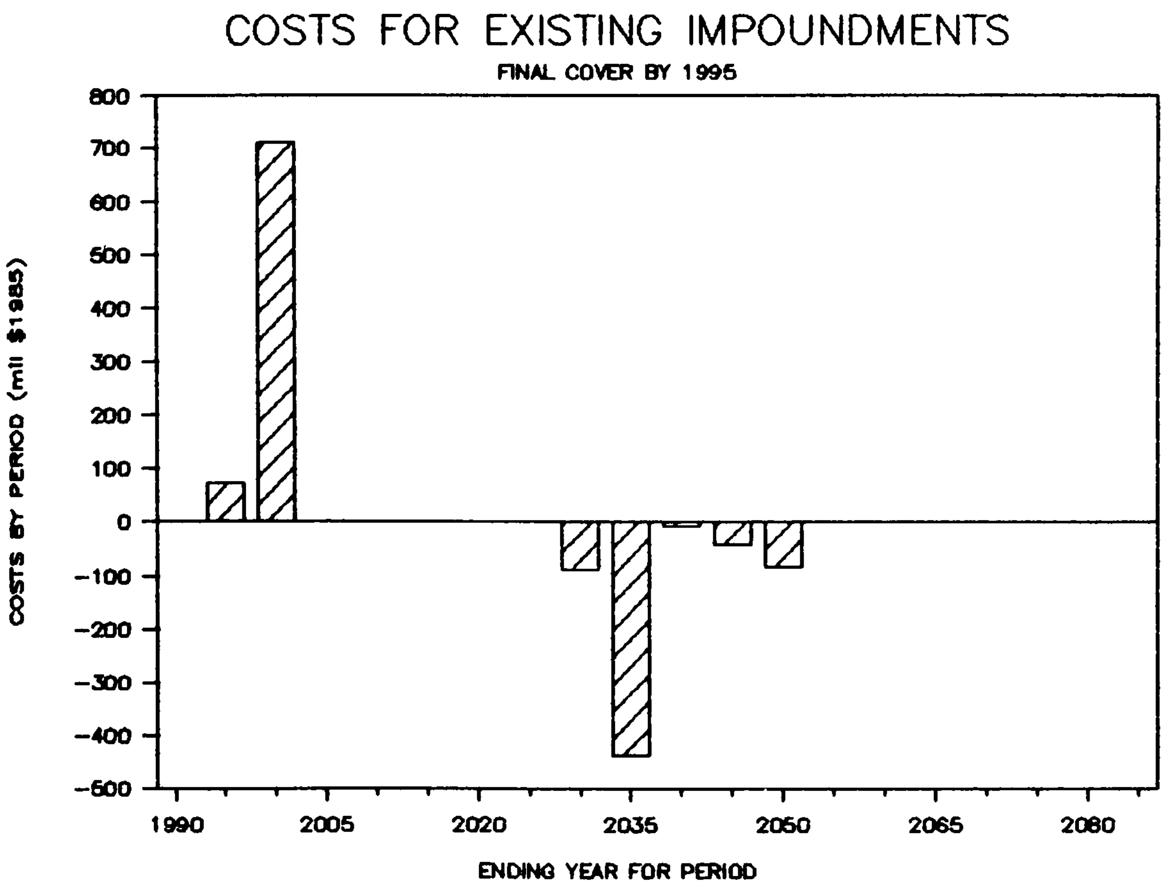


EXHIBIT 6-17C:

GRAPH OF ADDITIONAL COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2000

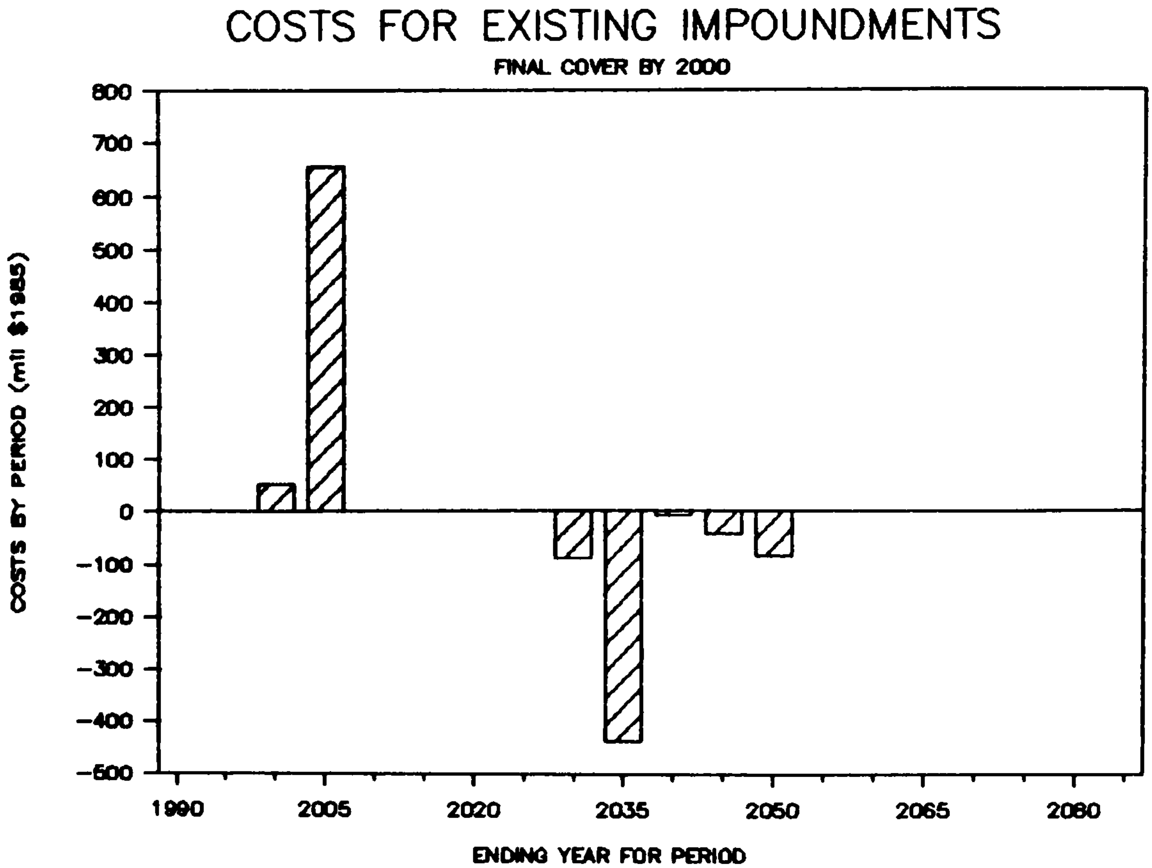


EXHIBIT 6-17D:

GRAPH OF ADDITIONAL COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2005

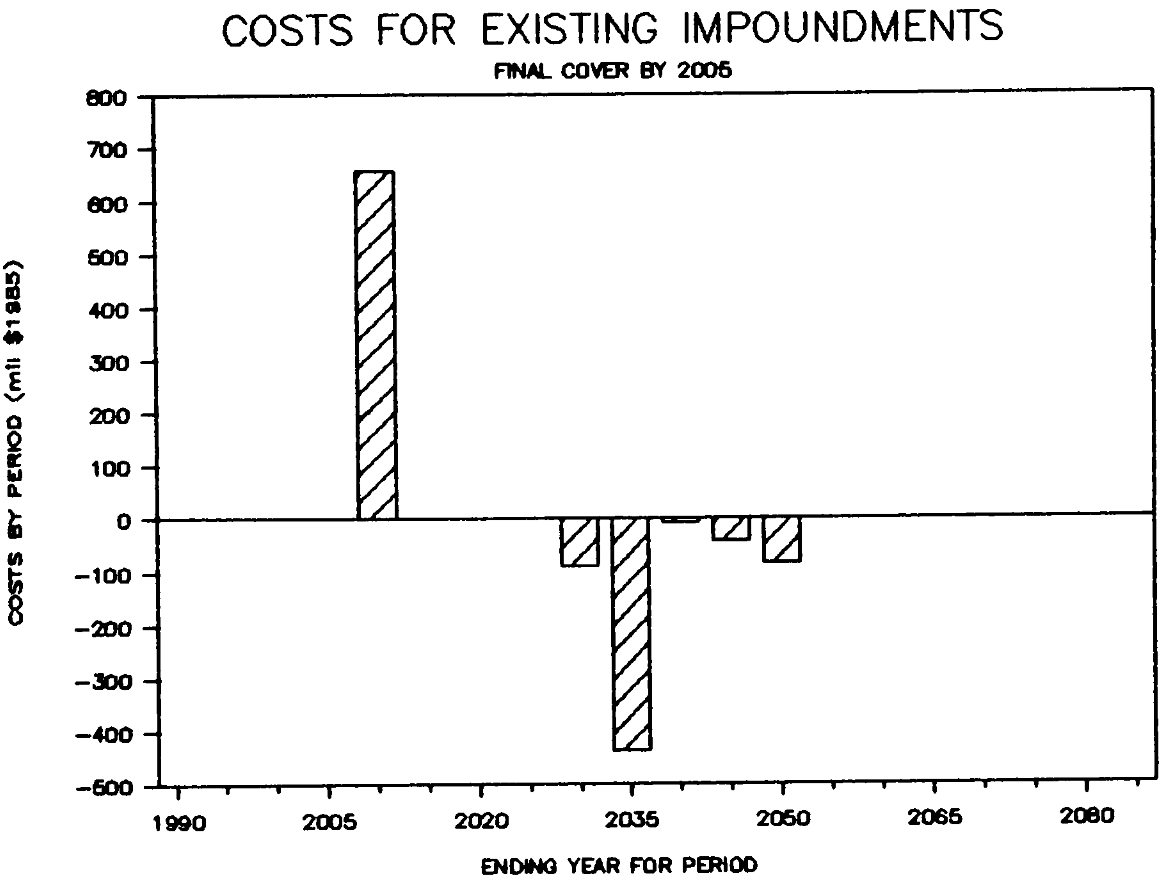
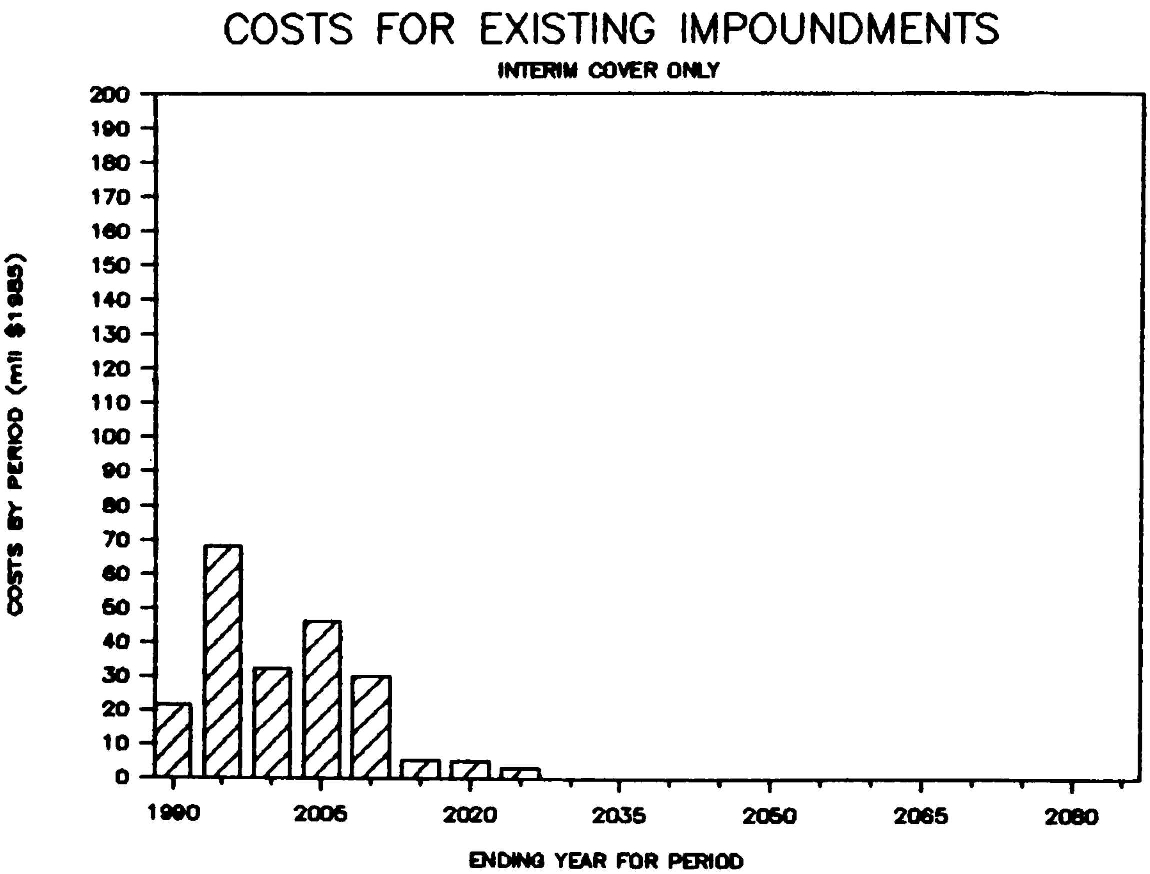


EXHIBIT 6-17E:

GRAPH OF ADDITIONAL COST OF INTERIM COVER AT EXISTING URANIUM MILLS



replacement impoundments and interim cover do not occur in the baseline cost stream. Both the total cost and present value cost for these type 1 cost items are positive, with monotonically decreasing present values for larger discount rates.

The disparate behavior of these two categories of costs as a function of the discount rate is examined in Exhibit 6-18, which contains graphs of the present value of a type 1 or type 2 cost payment of $1 at times t = 10 and t = 20 years in the future. The type 1 graphs start at $1 and uniformly decrease along the well-known exponential curve. The type 2 cost has a identical avoided cost of -$1 at a time 40 years after the time of payment. In this case, the total cost with no discount rate is zero. At higher discounts, the present value first increases then decreases, with the maximum present value occurring at a real discount rate of less than 5 percent. At discount rates of greater than 8 percent, the present value of the avoided cost payment 40 years later is almost zero. Hence, at discount rates higher than 8 percent, the present values of type 1 and type 2 costs are almost identical.

The distinction between type 1 and type 2 costs of the alternatives serves to separate the additional real resource costs of this rule from the opportunity value of costs for final stabilization which are required under other Federal statutes but which will be paid earlier as a result of this rule.

The results presented in Exhibits 6-16 (A through E) are summarized in Exhibit 6-19. The summary table shows the present value of the total social costs incurred by requiring the alternative work practices at existing mills. The present value cost at 5 percent and 10 percent of required expenditures for each cost category and total costs are shown for each alternative, where applicable. Alternatives which require final cover before 2005 have costs for replacement capacity, while the other alternatives do not require replacement of existing disposal capacity under the assumption that all existing mills cease operations by the year 2000.

6.3.4 Total Benefits Estimates — Existing Mills

The benefits of reduced radon-222 emissions resulting from adoption of the recommended work practices at existing licensed uranium mills were presented in Exhibit 6-9. These benefits occur due to earlier final stabilization of existing impoundments at current mill sites, and due to reduced operating emissions during disposal of future

EXHIBIT 6-18:

COMPARISON OF THE PRESENT VALUES OF TYPE 1 AND TYPE 2 COSTS AS A FUNCTION OF THE REAL DISCOUNT RATE

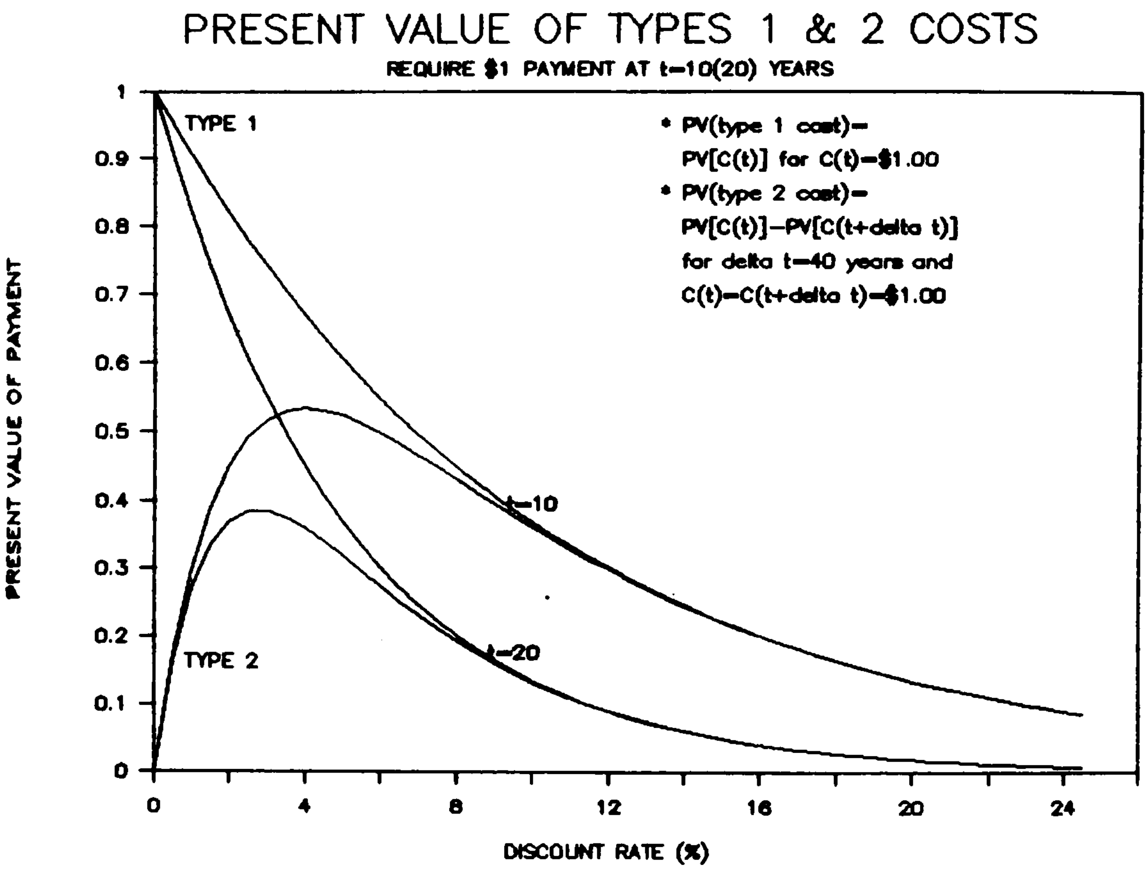


EXHIBIT 6-19:
PRESENT VALUE COSTS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS, FOR VARIOUS ALTERNATIVES

Present Value Cost (millions of 1985 dollars)

Control Alternative	5 Percent Discount				10 Percent Discount			
	Type 2[a]	Type 1[b]	Type 1		Type 2	Type 1	Type 1	
	Final Stabilization	Replacement Impoundments	Interim Stabilization	Total Cost	Final Stabilization	Replacement Impoundments	Interim Stabilization	Total Cost
1. Require new technology now, achieve final stabilization by 1990.	446	162	NA	608	400	138	NA	538
2. Require new technology by 1990, achieve final stabilization by 1995.	334	90	NA	424	245	66	NA	311
3. Require new technology by 1995, achieve final stabilization by 2000.	247	33	NA	280	149	21	NA	170
4. Require new technology by 2000, achieve final stabilization by 2005.	179	NA	NA	179	89	NA	NA	89
5. Interim stabilization only (1 meter)	NA	NA	151	151	NA	NA	97	97

[a]Type 2 costs represent the time value or the opportunity cost of stabilizing an impoundment sooner than it would have been stabilized in the absence of EPA action.

[b]Type 1 costs are due to the loss of disposal capacity in impoundments at existing mills, and the nonrecoverable cost of interim stabilization.

Note: Detail may not add to totals due to independent rounding.

tailings generated at these mills. The magnitude of the estimated benefits is strongly affected by our baseline assumption that existing impoundments will remain in a standby status for 40 years before final stabilization. A sensitivity analysis using a 20 year baseline assumption is presented in Chapter 7.

Estimates of baseline and avoided fatal lung cancers due to radon-222 emissions at existing mills are presented in Exhibits 6-20A through 6-20E for each alternative date of final cover for existing impoundments and for interim cover only. The avoided fatalities are reported in five-year periods for the local area (0-5 kilometers), the local region (5-80 kilometers), and for the rest of the nation. These estimates were developed by summing the site-specific health effects estimates presented in Exhibit 6-9, given the time pattern of future operations of existing mills implied by the baseline low-production scenario.

For alternatives which require final cover before 2005, the early closure of existing impoundments requires an earlier dry-out period which would not occur in the absence of this regulation. The higher emissions of these impoundments while drying cause negative benefits in the period preceding the date of final stabilization. These alternatives also require the construction of additional replacement impoundments, causing small negative benefits in the period after 2045. These effects are not encountered in the other alternatives. The benefits at existing mills are graphed in Exhibits 6-21A through 6-21E.

Exhibit 6-22 summarizes the estimated benefits of each alternative. In this exhibit, avoided fatalities in the local regional, and national categories are compared for each alternative. Significant reductions in baseline fatal cancer incidence rates are achievable by requiring the recommended work practices at all existing and future uranium mills, beginning now or at some near time in the future. The percent of baseline fatal cancers avoided by the alternatives ranges from 36 percent for interim cover only to 83 percent for final stabilization by 1990.

EXHIBIT 6-20A:

BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1990

(committed fatal cancers)

	baseline				Avoided Fatalities 1990			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.7	5.6	10.8	17.1	-0.1	-0.5	-1.0	-1.6
1991-95	0.8	6.8	12.9	20.5	0.8	6.4	12.2	19.4
1996-00	0.8	6.8	13.3	20.9	0.8	6.5	12.7	19.9
2001-05	0.9	7.2	14.2	22.3	0.8	6.9	13.6	21.4
2006-10	1.0	7.7	14.6	23.2	0.9	7.3	14.0	22.3
2011-15	1.0	7.7	14.6	23.2	0.9	7.3	14.0	22.3
2016-20	1.0	7.7	14.6	23.2	0.9	7.3	14.0	22.3
2021-25	1.0	7.7	14.6	23.2	0.9	7.3	14.0	22.3
2026-30	0.8	6.2	12.4	19.4	0.8	5.9	11.8	18.4
2031-35	0.2	1.6	3.6	5.4	0.1	1.3	3.0	4.5
2036-40	0.2	1.6	3.4	5.2	0.1	1.3	2.8	4.2
2041-45	0.2	1.5	2.4	4.1	0.1	1.2	1.8	3.1
2046-50	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2051-55	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2056-60	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2061-65	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2066-70	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2071-75	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2076-80	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2081-85	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
TOTAL	8.6	70.1	135.6	214.3	7.1	58.1	112.2	177.4

EXHIBIT 6-20B:

BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1995

(committed fatal cancers)

	baseline				Avoided Fatalities 1995			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.7	5.6	10.8	17.1	0.0	0.0	0.0	0.0
1991-95	0.8	6.8	12.9	20.5	-0.1	-0.5	-1.0	-1.6
1996-00	0.8	6.8	13.3	20.9	0.8	6.5	12.7	20.0
2001-05	0.9	7.2	14.2	22.3	0.8	7.0	13.6	21.4
2006-10	1.0	7.7	14.6	23.2	0.9	7.4	14.0	22.3
2011-15	1.0	7.7	14.6	23.2	0.9	7.4	14.0	22.3
2016-20	1.0	7.7	14.6	23.2	0.9	7.4	14.0	22.3
2021-25	1.0	7.7	14.6	23.2	0.9	7.4	14.0	22.3
2026-30	0.8	6.2	12.4	19.4	0.8	5.9	11.8	18.5
2031-35	0.2	1.6	3.6	5.4	0.1	1.3	3.0	4.5
2036-40	0.2	1.6	3.4	5.2	0.1	1.3	2.8	4.3
2041-45	0.2	1.5	2.4	4.1	0.1	1.2	1.8	3.1
2046-50	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2051-55	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2056-60	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2061-65	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2066-70	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2071-75	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2076-80	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2081-85	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
TOTAL	8.6	70.1	135.6	214.3	6.3	51.8	100.3	158.5

EXHIBIT 6-20C:
BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2000

	Avoided Fatalities							
	baseline				2000			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.7	5.6	10.8	17.1	0.0	0.0	0.0	0.0
1991-95	0.8	6.8	12.9	20.5	0.0	0.0	0.0	0.0
1996-00	0.8	6.8	13.3	20.9	-0.1	-0.4	-0.5	-1.1
2001-05	0.9	7.2	14.2	22.3	0.8	7.0	13.6	21.4
2006-10	1.0	7.7	14.6	23.2	0.9	7.4	14.1	22.3
2011-15	1.0	7.7	14.6	23.2	0.9	7.4	14.1	22.3
2016-20	1.0	7.7	14.6	23.2	0.9	7.4	14.1	22.3
2021-25	1.0	7.7	14.6	23.2	0.9	7.4	14.1	22.3
2026-30	0.8	6.2	12.4	19.4	0.8	5.9	11.9	18.5
2031-35	0.2	1.6	3.6	5.4	0.2	1.3	3.0	4.5
2036-40	0.2	1.6	3.4	5.2	0.1	1.3	2.8	4.3
2041-45	0.2	1.5	2.4	4.1	0.1	1.2	1.8	3.2
2046-50	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2051-55	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2056-60	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2061-65	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2066-70	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2071-75	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2076-80	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
2081-85	0.0	0.3	0.5	0.8	0.0	0.0	-0.1	-0.1
TOTAL	8.6	70.1	135.6	214.3	5.6	45.5	88.4	139.5

EXHIBIT 6-20D:

BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2005

(committed fatal cancers)

	baseline				Avoided Fatalities 2005			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.7	5.6	10.8	17.1	0.0	0.0	0.0	0.0
1991-95	0.8	6.8	12.9	20.5	0.0	0.0	0.0	0.0
1996-00	0.8	6.8	13.3	20.9	0.0	0.0	0.0	0.0
2001-05	0.9	7.2	14.2	22.3	0.0	0.0	0.0	0.0
2006-10	1.0	7.7	14.6	23.2	0.9	7.4	14.1	22.4
2011-15	1.0	7.7	14.6	23.2	0.9	7.4	14.1	22.4
2016-20	1.0	7.7	14.6	23.2	0.9	7.4	14.1	22.4
2021-25	1.0	7.7	14.6	23.2	0.9	7.4	14.1	22.4
2026-30	0.8	6.2	12.4	19.4	0.8	5.9	11.9	18.6
2031-35	0.2	1.6	3.6	5.4	0.2	1.4	3.1	4.6
2036-40	0.2	1.6	3.4	5.2	0.1	1.4	2.9	4.4
2041-45	0.2	1.5	2.4	4.1	0.1	1.3	1.8	3.3
2046-50	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2051-55	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2056-60	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2061-65	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2066-70	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2071-75	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2076-80	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2081-85	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
TOTAL	8.6	70.1	135.6	214.3	4.9	39.5	76.2	120.5

EXHIBIT 6-20E: BENEFITS OF INTERIM STABILIZATION AT EXISTING URANIUM MILLS

	Avoided Fatalities							
	baseline				INTERIM ONLY			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.7	5.4	10.3	16.5	0.1	0.7	1.1	1.9
1991-95	0.7	6.0	11.6	18.4	0.3	2.1	3.8	6.2
1996-00	0.7	5.4	10.8	16.8	0.2	1.4	2.8	4.3
2001-05	0.9	7.2	14.2	22.3	0.3	2.6	5.3	8.2
2006-10	1.0	7.7	14.6	23.2	0.4	3.3	6.4	10.1
2011-15	1.0	7.7	14.6	23.2	0.4	3.3	6.4	10.1
2016-20	1.0	7.7	14.6	23.2	0.4	3.3	6.4	10.1
2021-25	1.0	7.7	14.6	23.2	0.4	3.3	6.4	10.1
2026-30	0.8	6.2	12.4	19.4	0.3	2.5	5.0	7.8
2031-35	0.2	1.6	3.6	5.4	0.1	0.8	1.8	2.8
2036-40	0.2	1.6	3.4	5.2	0.1	0.8	1.7	2.6
2041-45	0.2	1.5	2.4	4.1	0.1	0.7	1.1	1.9
2046-50	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2051-55	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2056-60	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2061-65	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2066-70	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2071-75	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2076-80	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2081-85	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
TOTAL	8.4	67.7	131.5	207.6	3.2	25.0	48.2	76.3

EXHIBIT 6-21A:
GRAPH OF BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1990

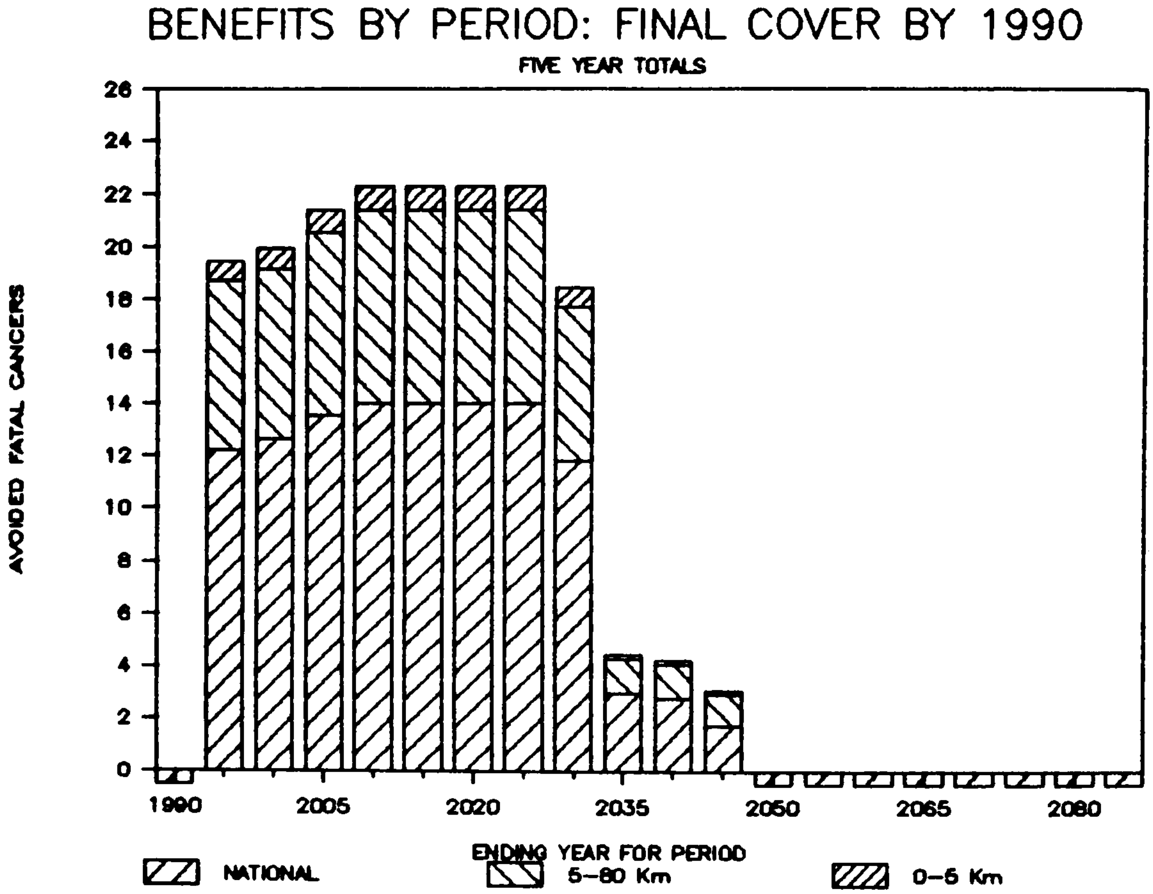


EXHIBIT 6-21B:

GRAPH OF BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1995

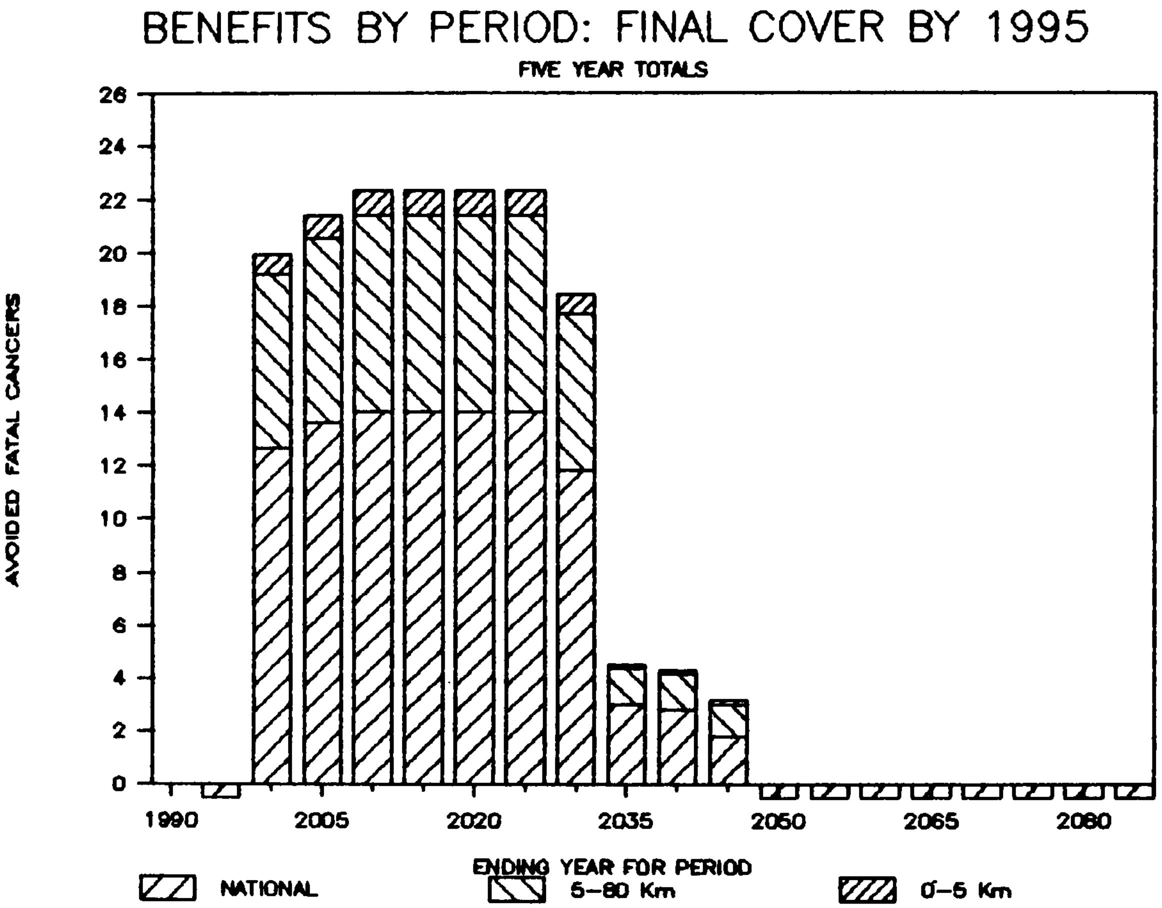


EXHIBIT 6-21C:

GRAPH OF BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2000

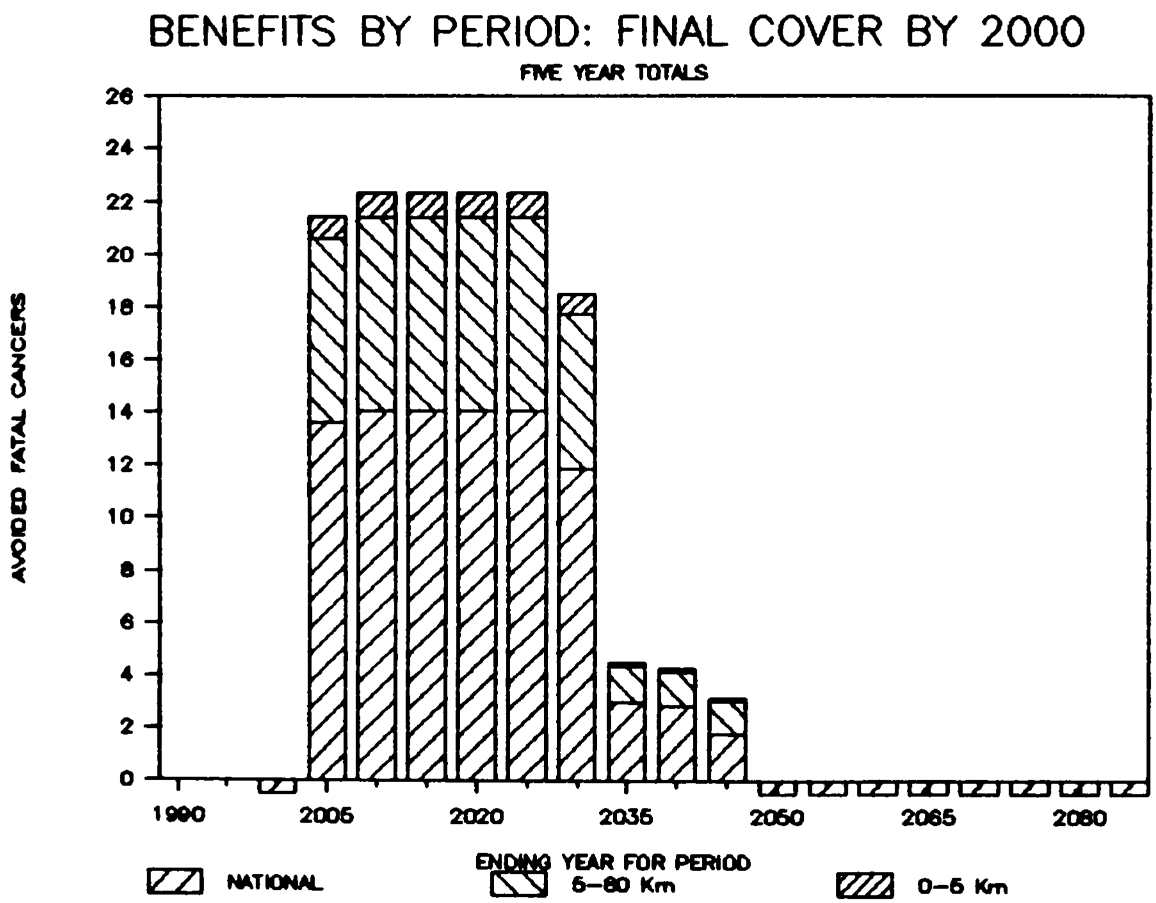


EXHIBIT 6-21D:

GRAPH OF BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2005

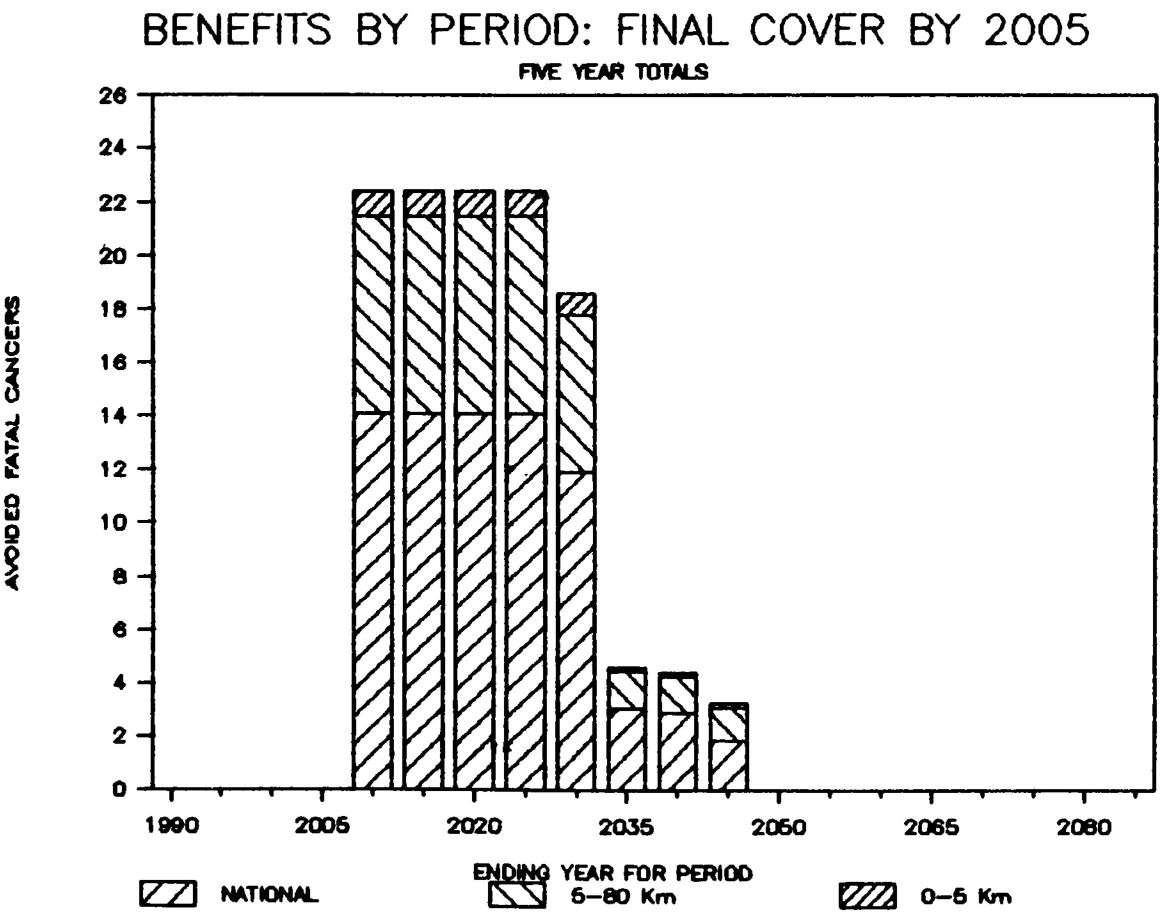


EXHIBIT 6-21E:

GRAPH OF BENEFITS OF INTERIM STABILIZATION

AT EXISTING URANIUM MILLS

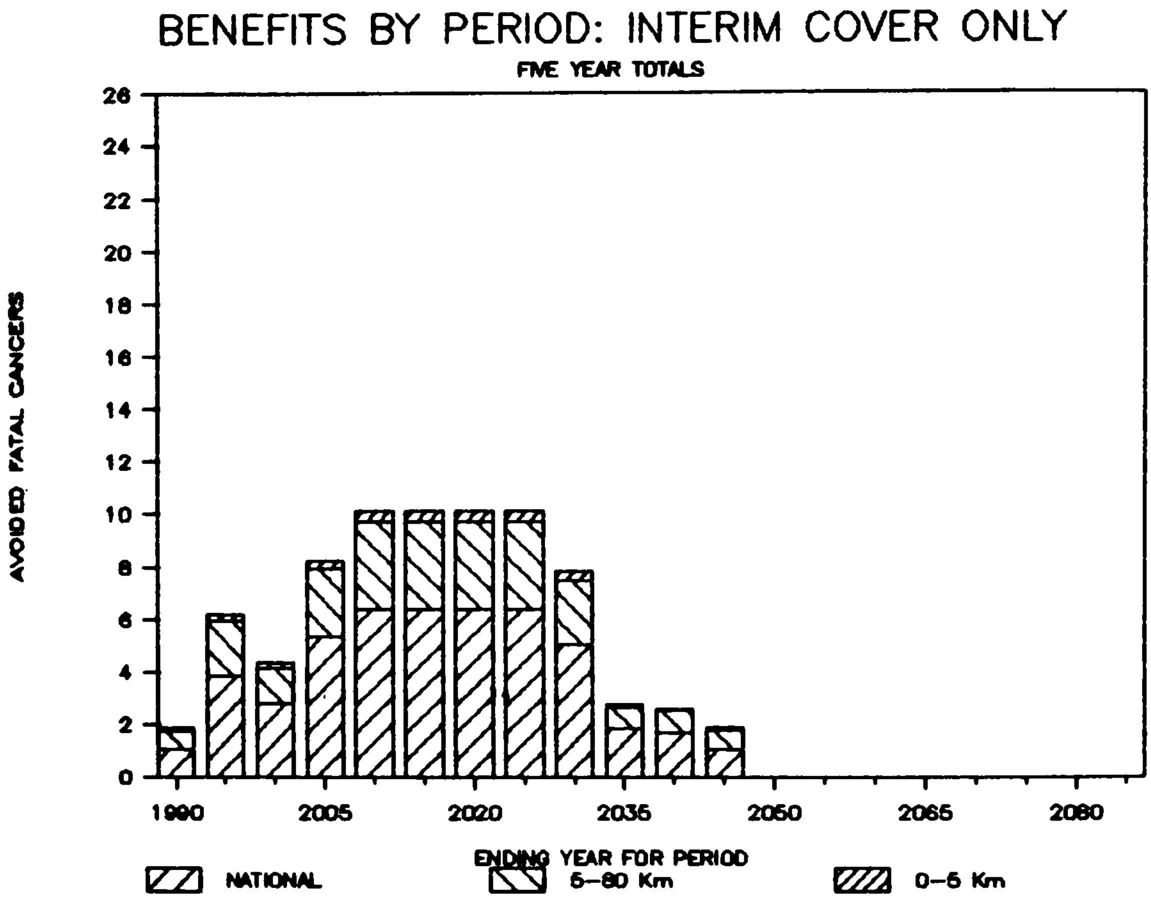


EXHIBIT 6-22:
FATALITIES AVOIDED BY ALTERNATIVE WORK PRACTICES AT EXISTING MILLS, BY YEAR OF FINAL STABILIZATION

Control Alternative	0-5Km		5-80 Km		Rest of Nation		Total	
	Avoided Fatalities	Percent Avoided	Avoided Fatalities	Percent Avoided	Avoided Fatalities	Percent Avoided	Avoided Fatalities	Percent Avoided
1. Require new technology now, achieve final stabilization by 1990.	7	78%	58	83%	112	82%	177	83%
2. Require new technology by 1990, achieve final stabilization by 1995.	6	67%	52	74%	100	74%	158	74%
3. Require new technology by 1995, achieve final stabilization by 2000.	6	67%	46	66%	89	65%	141	66%
4. Require new technology by 2000, achieve final stabilization by 2005.	5	56%	40	57%	76	56%	121	57%
5. Interim stabilization only (1 meter)	3	33%	25	36%	48	35%	76	36%
6. Baseline Fatalities	9		70		136		214	

Note: Detail may not add to totals due to independent rounding.

CHAPTER 7:

ESTIMATED TOTAL SOCIAL BENEFITS AND COSTS OF ALTERNATIVE WORK PRACTICES (20 YEAR BASELINE)

In Chapter 6 of the previous Draft Economic Analysis document, a "straw-man" assumption was introduced to enable measurement of the costs and benefits of the proposed emission control alternatives from a baseline scenario which defines the radon-222 emissions of existing impoundments in the absence of the current EPA action to further reduce these emissions. The assumption, simply stated, was that impoundments would not achieve final stabilization until 40 years after cessation of use. This hypothesis was referred to as the 40-year baseline assumption. In the sensitivity analysis (Section 6.4) of the Draft Economic Analysis, revised cost and benefit estimates were presented for an alternative 20-year baseline assumption. In the previous analysis, only total cost and total benefits were reported.

During the period for public comment which followed the release of the draft analysis, both State officials and industry representatives expressed concern that the 40-year period may be unrealistically long. Also during this period, several mills have submitted plans to the Nuclear Regulatory Commission for the decommissioning and final stabilization of impoundments which are no longer needed. Both facts point toward an earlier date of final stabilization for existing impoundments, thus increasing the likelihood that the 20-year baseline assumption better reflects actual future conditions in the absence of this EPA rulemaking. Due to this added likelihood, the cost and benefit estimates under the 20-year scenario are presented in detail in this chapter, rather than as a part of the sensitivity analysis which is now presented in Chapter 8 of this report.

7.1 TOTAL COST ESTIMATES: FUTURE MILLS

The DOE low domestic uranium production forecast led to the projection that 85 new mills and model new impoundments would be constructed between the years 2000 and 2085. The estimated unit costs of the alternative work practices at the future model mill were presented in Exhibits 6-1 through 6-3. For this analysis of the 20 year baseline assumption, cost data for the entirely below-grade impoundment are used. The

15-year periodicity of new mill costs which was described in Section 6.3.1 will be evident in all results presented in this section.

The estimated post-2000 life-cycle cost estimates developed for the alternative work practices at the 85 future impoundments under the 20 year baseline are presented in Exhibits 7-1A, 7-1B, and 7-1C. In these exhibits, total cost by period and cumulative costs are shown for the baseline single-cell impoundment at the future mills, with a 20-year dry standby period before final stabilization. Assuming the shorter period before final stabilization, i.e., 20 years, generates lower cost estimates for all alternatives at new impoundments.

As in the 40 year baseline analysis of Chapter 6, the total additional real resource cost streams for the alternative work practices are obtained by subtracting the baseline life-cycle cost stream from the life-cycle cost stream under the alternative work practice, yielding the net additional cost of the alternative in each year. This quantity is labeled in the exhibits as the "added cost" of the alternative. Present values of each cost stream are shown at the bottom of each column. The present value costs are calculated in 1985 dollars, assuming that all costs in a five-year period are expended at the beginning of the period. The added present value cost of each alternative is small, due to the large time span between the present time and the beginning of operation of the first new model mills in the year 2000.

The total undiscounted life-cycle cost of the single impoundment option, with final cover five years after filling, are identical to the costs for the baseline, which assumes the same disposal system but with final stabilization occurring 20 years later. Although total added costs for this alternative sum to zero over the time frame selected for analysis, the present values of the added cost stream for this alternative are positive. This reflects the lost opportunity value associated with the earlier time of final stabilization required under the alternative.

The costs for the phased disposal alternative shown in Exhibit 7-1B has total life-cycle costs under the 20 year assumption which are again approximately 15 percent higher than for the baseline impoundment. But a large portion of excavation costs are incurred later in time for each mill, due to the more uniform pattern of expenses for the phased disposal shown in Exhibit 6-3. This timing advantage for phased disposal

EXHIBIT 7-1(A):

COST OF AN ALTERNATIVE WORK PRACTICE

AT FUTURE URANIUM MILLS — COVER IN FIVE YEARS AFTER FILLING

(millions 1985 dollars)

(20 year baseline)

	baseline		COVER IN 5 YEARS		added cost	
PERIOD	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE
1986-90	0	0	0	0	0	0
1991-95	0	0	0	0	0	0
1996-00	0	0	0	0	0	0
2001-05	268	268	268	268	0	0
2006-10	33	301	33	301	0	0
2011-15	33	334	33	334	0	0
2016-20	301	636	301	636	0	0
2021-25	67	702	130	765	63	63
2026-30	67	769	75	840	8	71
2031-35	334	1104	342	1183	8	79
2036-40	67	1171	138	1320	71	150
3041-45	163	1334	116	1437	-47	102
2046-50	342	1676	350	1787	8	110
2051-55	108	1785	179	1966	71	181
2056-60	171	1956	116	2082	-55	126
2061-65	384	2340	392	2474	8	134
2066-70	116	2456	179	2653	63	197
2071-75	179	2635	124	2777	-55	142
2076-80	384	3019	392	3168	8	150
2081-85	124	3143	187	3355	63	213
post-2085	370	3513	158	3513	-213	0
TOTAL	3513		3513		0	
PV(1%)	1912		1969		58	
PV(5%)	348		366		19	
PV(10%)	101		104		3.0	

(*) Post-2085 costs include all remaining life-cycle costs for impoundments started before 2085 by not covered by that date. All post-2085 costs are expressed in present value in the year 2085.

EXHIBIT 7-1(B):
COST OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — PHASED DISPOSAL

(millions 1985 dollars)

(20 year baseline)

	baseline		PHASED DISPOSAL		added cost	
PERIOD	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE
1986-90	0	0	0	0	0	0
1991-95	0	0	0	0	0	0
1996-00	0	0	0	0	0	0
2001-05	268	268	104	104	-164	-164
2006-10	33	301	129	232	95	-69
2011-15	33	334	155	387	122	53
2016-20	301	636	171	558	-130	-77
2021-25	67	702	187	745	120	43
2026-30	67	769	203	948	136	179
2031-35	334	1104	219	1167	-116	63
2036-40	67	1171	222	1388	155	218
3041-45	163	1334	236	1625	73	291
2046-50	342	1676	238	1862	-105	186
2051-55	108	1785	252	2114	144	330
2056-60	171	1956	254	2368	82	412
2061-65	384	2340	268	2636	-116	297
2066-70	116	2456	270	2906	153	450
2071-75	179	2635	271	3177	92	542
2076-80	384	3019	271	3448	-113	429
2081-85	124	3143	271	3719	147	576
post-2085	370	3513	347	4066	-23	553
	3513		4066		553	
PV(1%)	1912		2218		306	
PV(5%)	348		363		15	
PV(10%)	101		87		-14	

') Post-2085 costs include all remaining life-cycle costs for impoundments started before 2085 by not covered by that date. All post-2085 costs are expressed in present value in the year 2085.

EXHIBIT 7-1(C):

COST OF AN ALTERNATIVE WORK PRACTICE

AT FUTURE URANIUM MILLS — CONTINUOUS DISPOSAL

(millions 1985 dollars)

(20 year baseline)

	baseline		CONTINUOUS DISPOSAL		added cost	
PERIOD	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE	TOTAL	CUMULATIVE
1986-90	0	0	0	0	0	0
1991-95	0	0	0	0	0	0
1996-00	0	0	0	0	0	0
2001-05	268	268	144	144	-123	-123
2006-10	33	301	163	307	129	6
2011-15	33	334	181	488	147	153
2016-20	301	636	199	686	-102	51
2021-25	67	702	217	903	150	200
2026-30	67	769	235	1138	168	368
2031-35	334	1104	253	1390	-82	287
2036-40	67	1171	253	1643	186	473
3041-45	163	1334	271	1914	107	580
2046-50	342	1676	271	2185	-72	509
2051-55	108	1785	289	2474	181	689
2056-60	171	1956	289	2763	118	807
2061-65	384	2340	307	3070	-77	730
2066-70	116	2456	307	3377	191	921
2071-75	179	2635	307	3684	128	1049
2076-80	384	3019	307	3991	-77	972
2081-85	124	3143	307	4298	183	1155
post-2085	370	3513	307	4605	-63	1092
	3513		4605		1092	
PV(1%)	1912		2546		634	
PV(5%)	348		435		88	
PV(10%)	101		109		7.9	

(*) Post-2085 costs include all remaining life-cycle costs for impoundments started before 2085 by not covered by that date. All post-2085 costs are expressed in present value in the year 2085.

reduces the difference in costs when present values are calculated. At a 5 percent discount rate, life-cycle costs for phased disposal are approximately equal to those for the baseline. At a 10 percent discount rate, the present value cost of phased disposal is less than that for the baseline impoundment. These results are identical to those noted in the previous chapter for the 40 years baseline.

The total life-cycle costs under the 20 year baseline for the continuous disposal option, shown in Exhibit 7-1C, are higher than for the baseline impoundment. Continuous disposal also has a timing advantage in the delayed expenditure of funds for excavation costs. Hence the cost difference between continuous disposal and the baseline disposal method also decreases at higher discount rates. At a 5 percent discount the total life-cycle cost streams differ by 25 percent; and at a 10 percent discount, by only 8 percent.

Graphs of the total added cost streams for each alternative are shown in Exhibits 7-2A, 7-2B, and 7-2C. These cost streams for the 20 year baseline exhibit the 15 year periodicity note above in the 40 year baseline analysis.

The present values of the estimated added life-cycle cost streams under the 20 year assumption for each alternative work practice at future uranium mills are summarized in Exhibit 7-3. In this exhibit the present value cost at a 5 percent and 10 percent discount rate for the baseline disposal method are compared to the present value cost of each alternative. The added cost for each alternative and the percent increase in present value cost are also presented. Comparison with Exhibit 6-12 shows that there is little change in the 10 percent discounted costs for new mills as a result of changing the 40 year baseline assumption to 20 years. At a 5 percent discount, the added cost of alternative 1, large single-cell impoundments covered in five years, decreases from $26 million under the 40 year assumption to approximately $19 million under the 20 year assumption. Corresponding decreases for phased and continuous disposal are $22 million to $15 million, and from $95 million to $88 million, respectively. In percentage terms, the change to a 20 year baseline assumption decreases costs for alternative 1 by 26 percent, the cost of phased disposal by 32 percent, and continuous disposal by 8 percent.

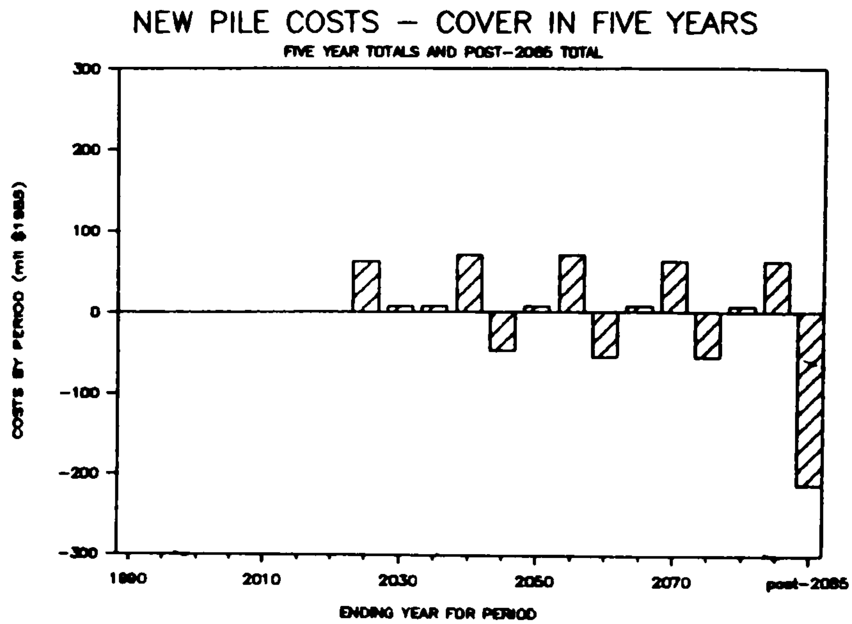
7.2 TOTAL BENEFITS ESTIMATES: FUTURE MILLS

The estimated benefits of each alternative work practice at existing mill sites are calculated using site-specific health-effects factors computed using EPA-AIRDOS, based on the site-specific emissions estimates and local populations. This procedure

EXHIBIT 7-2(A):

GRAPHS OF ADDED COST AND CUMULATIVE ADDED COST OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — COVER IN FIVE YEARS AFTER FILLING

(20 year baseline)



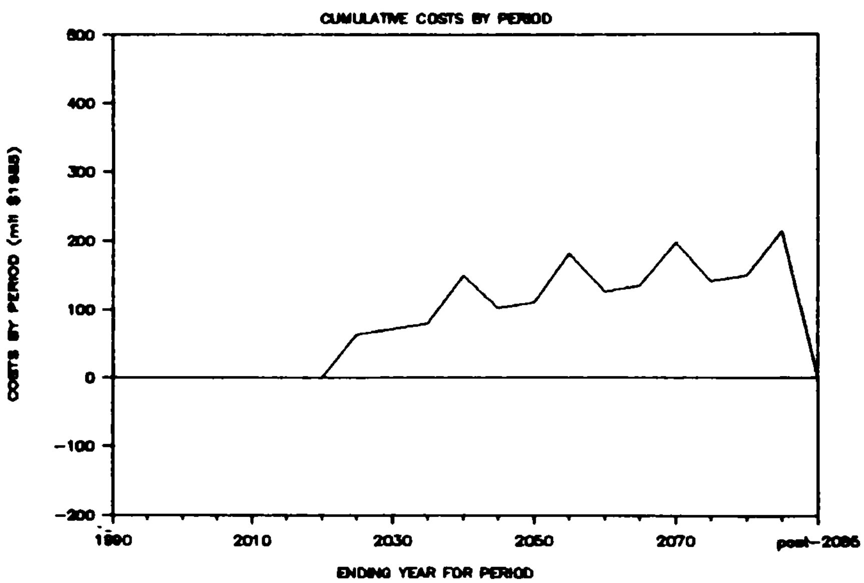
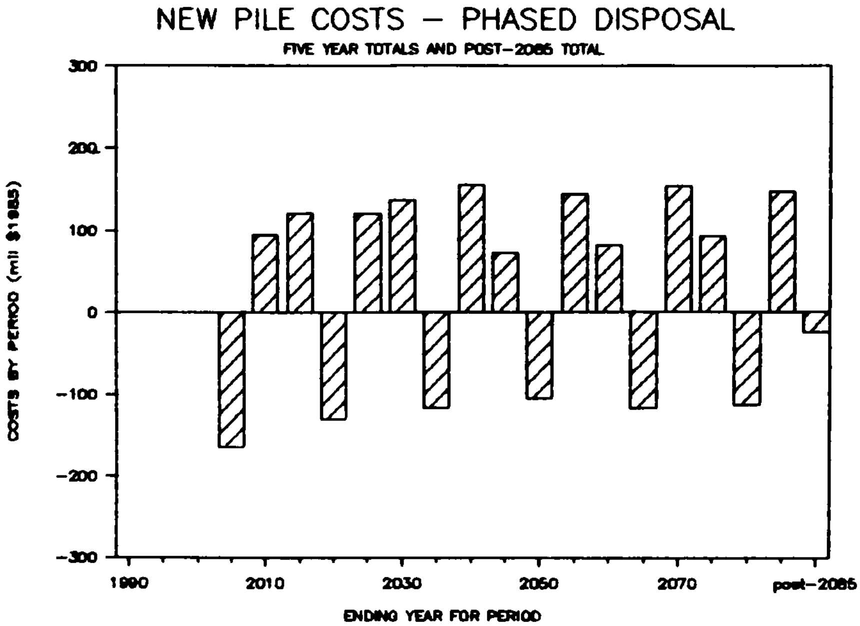


EXHIBIT 7-2(B):

GRAPHS OF ADDED COST AND CUMULATIVE ADDED COST OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — PHASED DISPOSAL

(20 year baseline)



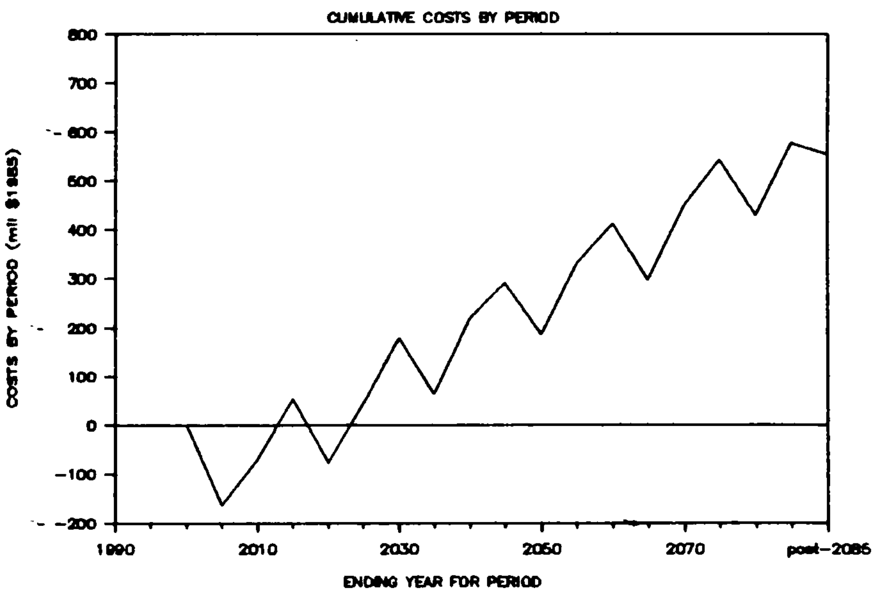
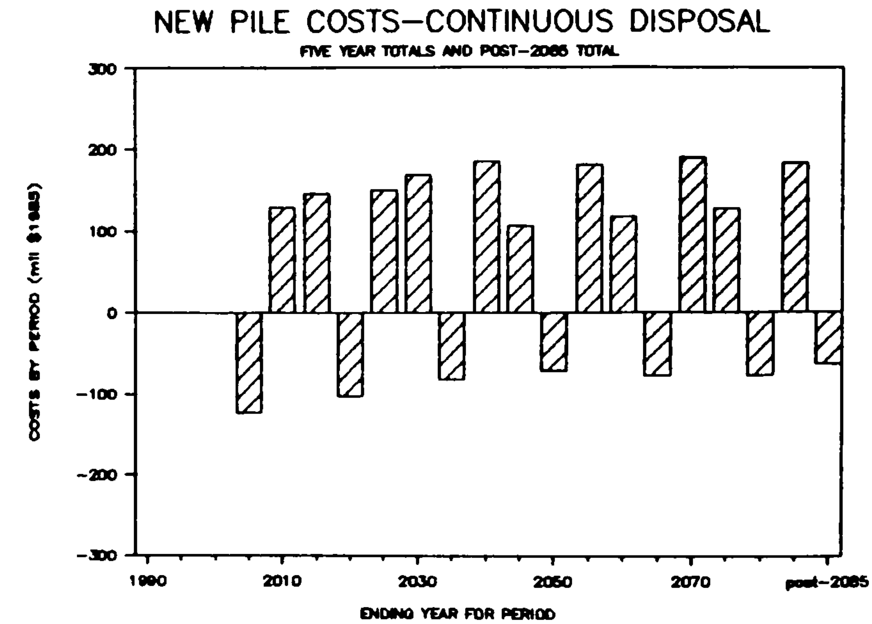


EXHIBIT 7-2(C):

GRAPHS OF ADDED COST AND CUMULATIVE ADDED COST OF
AN ALTERNATIVE WORK PRACTICE AT
FUTURE URANIUM MILLS — CONTINUOUS DISPOSAL

(20 year baseline)



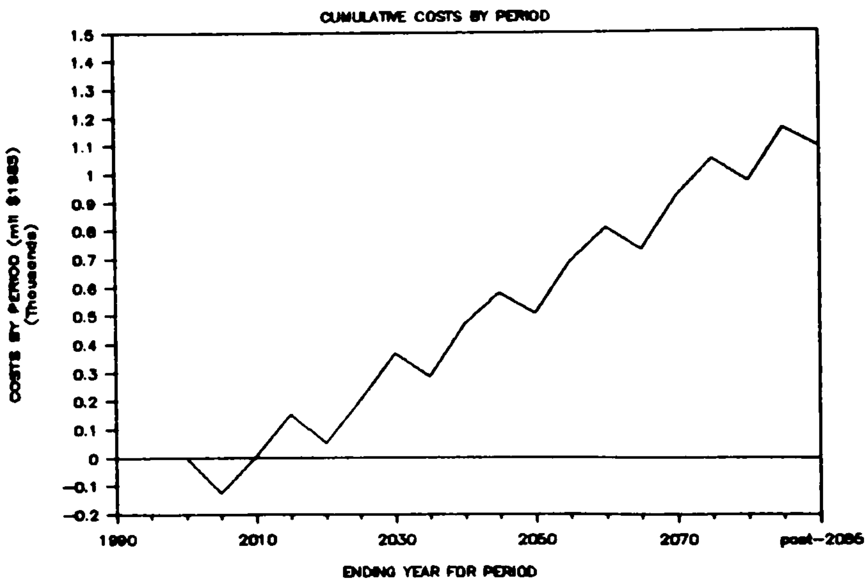


EXHIBIT 7-3:

PRESENT VALUE COST OF ALTERNATIVE WORK PRACTICES AT FUTURE URANIUM MILLS

(millions of 1985 dollars)

(20 years baseline)

	5 Percent Discount Rate		10 Percent Discount Rate	
Alternative Work Practice For New Impoundments	Cost of Alternative	Added Cost (%)	Cost of Alternative	Added Cost (%)
1. Baseline impoundments covered in 5 years	367	19 (5%)	104	3.0 (3%)
2. Phased disposal	363	15 (4%)	87	-13 (-13%)
3. Continuous disposal	436	88 (25%)	109	7.9 (8%)
Baseline impoundment covered in 20 years	348	—	101	—

was described in some detail in Sections 6.2 and 6.3.2 above. The benefits estimates for existing mills are discussed at the end of this section.

Estimated benefits under the 20 year assumption for the alternative work practices at the 85 new model mills projected to be on-line in the years 2000 to 2085 are presented in Exhibits 7-4A, 7-4B, and 7-4C. In these exhibits, baseline fatalities and avoided fatalities for each alternative are shown for the local, regional and rest of nation regions and in total for each of the five-year periods. Total health effects over the 85 year period are listed at the bottom of each column. The benefits and cumulative benefits at future mill sites are graphed for each alternative in Exhibits 7-5A, 7-5B, and 7-5C.

A summary of the 20 year baseline benefits shown in Exhibits 7-4 is contained in Exhibit 7-6. Comparison of this exhibit to Exhibit 6-15 shows that all three alternative new impoundment work practices result in substantial fewer benefits when compared to the 40-year baseline estimates.

Under the 20 year assumption, total baseline fatalities resulting from radon-222 emissions at new future mills are decreased from 312 to 180, a decrease of 42 percent. This decrease is a result of the shorter assumed period of high emissions from dry impoundments between cessation of operation and the time of final stabilization. This decrease in estimated baseline fatalities is reflected in reduced benefits achieved by the alternative work practices at future mills. Benefits achieved by alternative 1, covering large single-cell impoundments within five years of filling, are reduced by 50 percent, from 251 to 126. The benefits achieved by phased disposal, alternative 2, are reduced by 47 percent, from 268 under the 40 year baseline assumption to 143 under the revised 20-year baseline assumption. Benefits for continuous disposal, alternative 3, are reduced by 45 percent, from 276 to 151.

Because the percent reductions in achieved benefits exceed the percent reduction in baseline fatalities, the percentage of baseline fatalities avoided by all alternatives under the 20 year assumption are slightly lower than the corresponding percentage reductions achieved under to 40-year baseline assumption. Hence the effectiveness of

EXHIBIT 7-4(A):

BENEFITS OF AN ALTERNATIVE WORK PRACTICE

AT FUTURE URANIUM MILLS — COVER IN FIVE YEARS AFTER FILLING

(committed fatal cancers)

(20 year baseline)

	baseline				Avoided Fatalities: COVER IN 5 YEARS			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991-95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996-00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001-05	0.0	0.2	0.4	0.6	0.0	0.0	0.0	0.0
2006-10	0.0	0.2	0.4	0.7	0.0	0.0	0.0	0.0
2011-15	0.0	0.2	0.5	0.8	0.0	0.0	0.0	0.0
2016-20	0.1	0.9	1.7	2.7	0.0	0.0	0.0	0.0
2021-25	0.2	1.4	2.7	4.3	0.1	1.0	1.9	3.0
2026-30	0.2	1.6	3.0	4.8	0.1	1.1	2.1	3.3
2031-35	0.3	2.3	4.5	7.2	0.2	1.2	2.3	3.7
2036-40	0.4	2.9	5.8	9.1	0.3	2.3	4.4	7.0
2041-45	0.3	2.3	4.4	7.0	0.2	1.6	3.0	4.8
2046-50	0.4	3.0	5.9	9.3	0.2	1.7	3.3	5.2
2051-55	0.5	3.6	7.0	11.1	0.4	2.7	5.4	8.5
2056-60	0.4	2.9	5.6	8.8	0.3	1.9	3.7	5.9
2061-65	0.5	3.6	7.0	11.0	0.3	2.0	4.0	6.3
2066-70	0.5	4.1	8.0	12.6	0.4	3.0	5.9	9.2
2071-75	0.4	3.3	6.4	10.1	0.3	2.2	4.2	6.7
2076-80	0.5	4.0	7.9	12.5	0.3	2.3	4.4	7.0
2081-85	0.6	4.5	8.8	13.8	0.4	3.2	6.3	10.0
post-2085	2.4	17.4	34.1	53.9	2.0	14.6	28.5	45.1
TOTAL	7.9	58.3	114.2	180.4	5.5	40.6	79.6	125.7

EXHIBIT 7-4(B):

BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — PHASED DISPOSAL

(committed fatal cancers)

(20 year baseline)

	baseline				Avoided Fatalities: PHASED DISPOSAL			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991-95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996-00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001-05	0.0	0.2	0.4	0.6	0.0	0.0	0.0	0.1
2006-10	0.0	0.2	0.4	0.7	0.0	0.0	0.1	0.1
2011-15	0.0	0.2	0.5	0.8	0.0	0.0	0.1	0.1
2016-20	0.1	0.9	1.7	2.7	0.1	0.5	0.9	1.5
2021-25	0.2	1.4	2.7	4.3	0.1	1.0	2.1	3.2
2026-30	0.2	1.6	3.0	4.8	0.2	1.2	2.3	3.6
2031-35	0.3	2.3	4.5	7.2	0.2	1.7	3.4	5.4
2036-40	0.4	2.9	5.8	9.1	0.3	2.4	4.7	7.5
2041-45	0.3	2.3	4.4	7.0	0.2	1.7	3.3	5.3
2046-50	0.4	3.0	5.9	9.3	0.3	2.3	4.4	7.0
2051-55	0.5	3.6	7.0	11.1	0.4	2.9	5.7	9.0
2056-60	0.4	2.9	5.6	8.8	0.3	2.1	4.2	6.6
2061-65	0.5	3.6	7.0	11.0	0.4	2.6	5.2	8.1
2066-70	0.5	4.1	8.0	12.6	0.4	3.2	6.3	9.9
2071-75	0.4	3.3	6.4	10.1	0.3	2.4	4.6	7.3
2076-80	0.5	4.0	7.9	12.5	0.4	2.9	5.7	9.1
2081-85	0.6	4.5	8.8	13.8	0.5	3.4	6.7	10.7
post-2085	2.4	17.4	34.1	53.9	2.1	15.6	30.5	48.1
TOTAL	7.9	58.3	114.2	180.4	6.2	46.1	90.3	142.6

EXHIBIT 7-4(C):
BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — CONTINUOUS DISPOSAL
(committed fatal cancers)

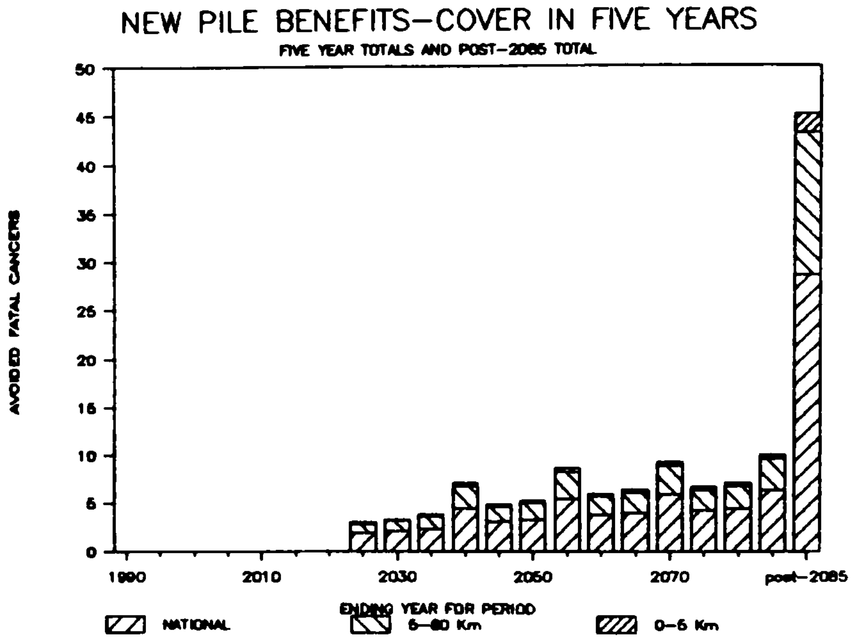
(20 year baseline)

	baseline				Avoided Fatalities CONTINUOUS DISPOSAL			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991-95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996-00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001-05	0.0	0.2	0.4	0.6	0.0	0.1	0.1	0.2
2006-10	0.0	0.2	0.4	0.7	0.0	0.1	0.2	0.3
2011-15	0.0	0.2	0.5	0.8	0.0	0.1	0.2	0.3
2016-20	0.1	0.9	1.7	2.7	0.1	0.6	1.3	2.0
2021-25	0.2	1.4	2.7	4.3	0.2	1.1	2.2	3.5
2026-30	0.2	1.6	3.0	4.8	0.2	1.3	2.5	3.9
2031-35	0.3	2.3	4.5	7.2	0.3	1.9	3.8	6.0
2036-40	0.4	2.9	5.8	9.1	0.3	2.5	5.0	7.8
2041-45	0.3	2.3	4.4	7.0	0.2	1.8	3.6	5.6
2046-50	0.4	3.0	5.9	9.3	0.3	2.5	4.9	7.7
2051-55	0.5	3.6	7.0	11.1	0.4	3.0	5.9	9.4
2056-60	0.4	2.9	5.6	8.8	0.3	2.3	4.4	7.0
2061-65	0.5	3.6	7.0	11.0	0.4	2.9	5.6	8.9
2066-70	0.5	4.1	8.0	12.6	0.5	3.3	6.6	10.3
2071-75	0.4	3.3	6.4	10.1	0.3	2.5	4.9	7.8
2076-80	0.5	4.0	7.9	12.5	0.4	3.2	6.2	9.8
2081-85	0.6	4.5	8.8	13.8	0.5	3.6	7.0	11.1
post-2085	2.4	17.4	34.1	53.9	2.1	15.9	31.1	49.1
TOTAL	7.9	58.3	114.2	180.4	6.6	48.7	95.4	150.6

<u>EXHIBIT 7-5(A):</u>

<u>GRAPHS OF BENEFITS AND CUMULATIVE BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — COVER IN FIVE YEARS AFTER FILLING</u>

(20 year baseline)



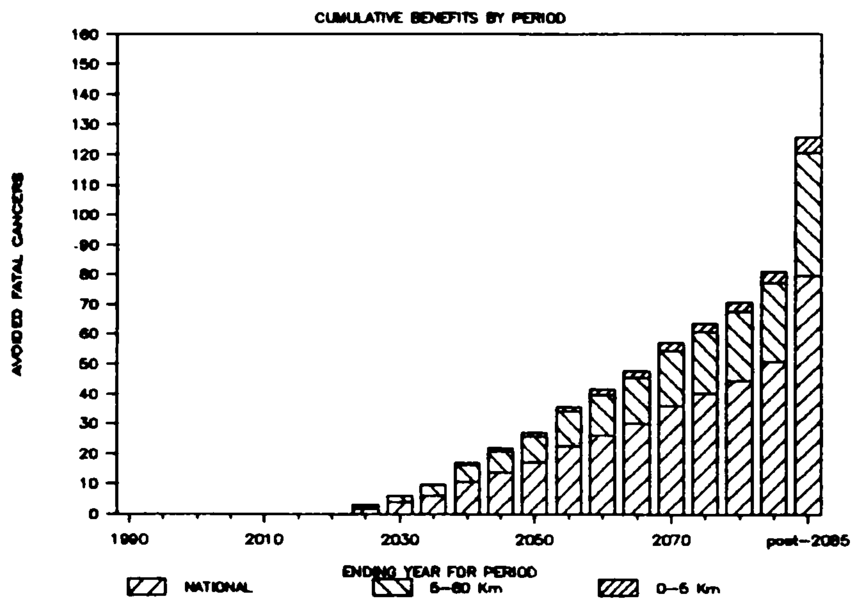
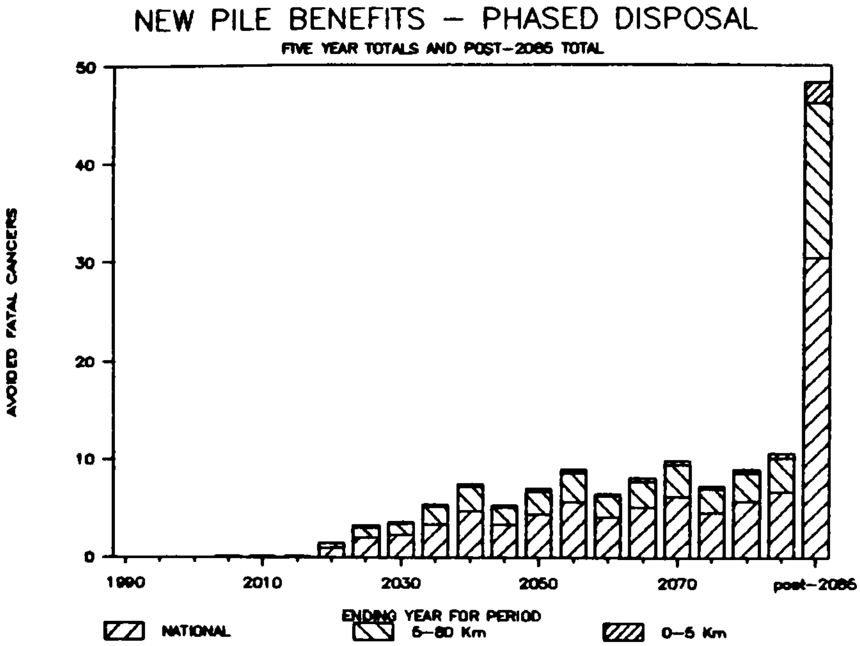


EXHIBIT 7-5(B):

GRAPHS OF BENEFITS AND CUMULATIVE BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — PHASED DISPOSAL

(20 year baseline)



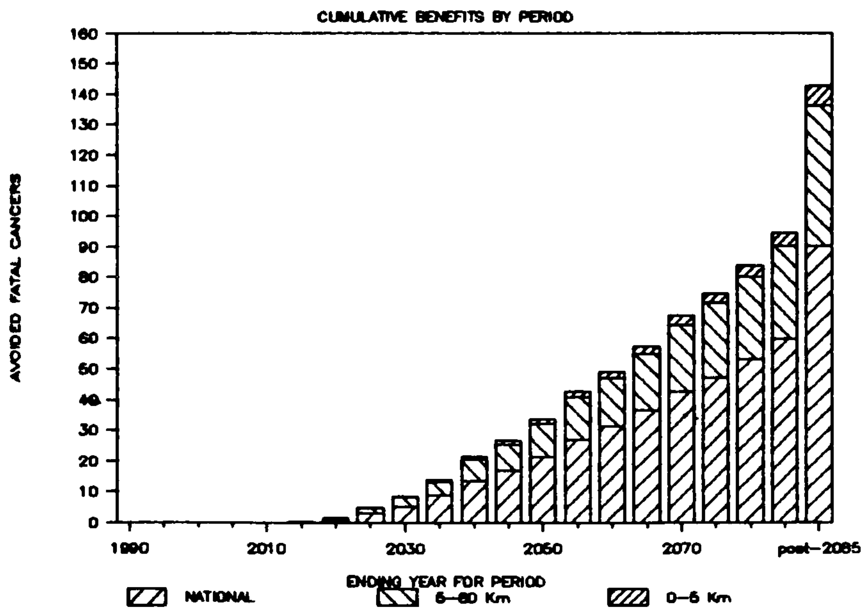
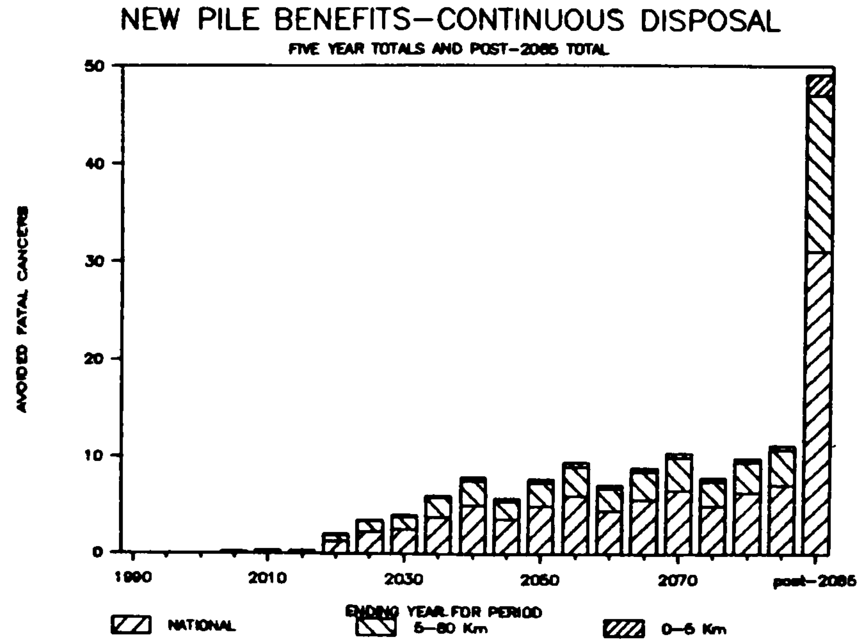


EXHIBIT 7-5(C):

GRAPHS OF BENEFITS AND CUMULATIVE BENEFITS OF AN ALTERNATIVE WORK PRACTICE AT FUTURE URANIUM MILLS — CONTINUOUS DISPOSAL

(20 year baseline)



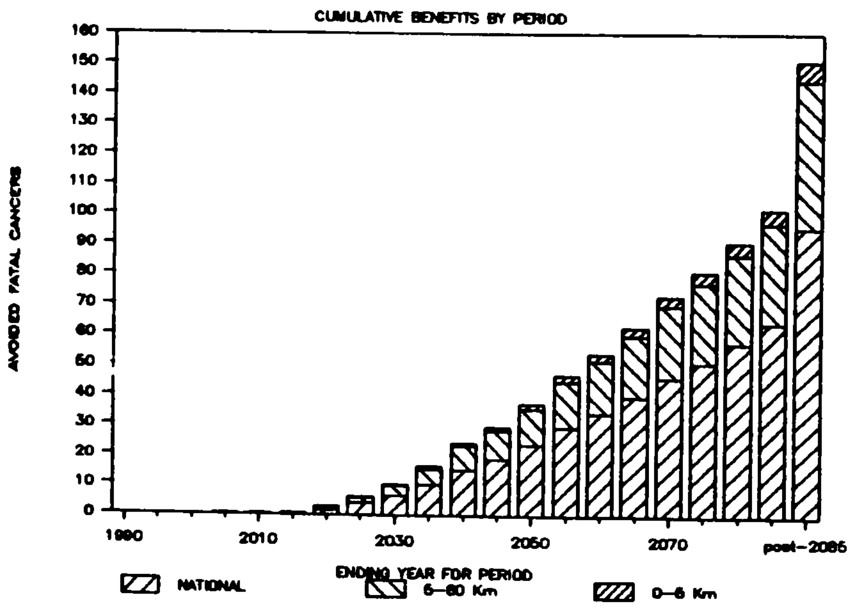


EXHIBIT 7-6:

SUMMARY OF BENEFITS OF ALTERNATIVE WORK PRACTICES AT FUTURE URANIUM MILLS

(20 year baseline)

	0-5 Km			5-80 Km			Rest of Nation			Total		
Alternative	Baseline Fatalities	Avoided Fatalities	Percent Avoided	Baseline Fatalities	Avoided Fatalities	Percent Avoided	Baseline Fatalities	Avoided Fatalities	Percent Avoided	Baseline Fatalities	Avoided Fatalities	Percent Avoided
1. Baseline Impound-ments (cover in 5 years)	7.9	5.5	69%	58.3	40.6	70%	114.2	79.6	70%	180.4	125.7	70%
2. Phased Disposal	7.9	6.2	78%	58.3	46.1	79%	114.2	90.3	79%	180.4	142.6	79%
3. Continuous Disposal	7.9	6.6	84%	58.3	48.7	84%	114.2	95.4	84%	180.4	150.6	84%

alternative 1 in avoiding baseline fatalities falls from 81 percent (Exhibit 6-15) to 70 percent (last column of Exhibit 7-6). Similar, but smaller, reductions in effectiveness occur for alternatives 2 and 3.

7.3 TOTAL COST ESTIMATES: EXISTING MILLS

As for the 40-year baseline analysis, estimates of the total cost of the alternatives at existing licensed mill sites under the 20 year assumption are derived by comparing the baseline disposal cost stream with the cost stream required for disposal under each alternative. The additional real resource cost resulting from each alternative is obtained by subtracting baseline cost from the cost of the alternative in each time period, then taking the present value of the stream of additional costs. Three types of cost may be incurred: opportunity cost associated with moving up the time of final cover expenses, replacement costs for tailings disposal in new impoundments, and interim cover costs to the extent these costs are not recoverable at the time of final stabilization.

A detailed description of procedures for estimating costs at existing mills was presented in Section 6.3.3 above. Specific assumptions presented there concerning sunk costs, replacement costs, and interim cover costs are also applicable to this analysis under the 20 year assumption.

Estimates of the additional cost of each alternative at existing mills are presented in Exhibits 7-7A through 7-7E. The costs in the exhibit are expressed in 1985 dollars, and the total cost streams are separated into cost streams for final stabilization (cover), replacement of lost capacity, and interim cover. Baseline cost streams are presented in the left-most columns, estimated cost streams under each alternative are shown in the center columns, and the net additional cost stream for the alternative in the right-most columns. The present values at the bottom of each column were calculated assuming costs are incurred at the beginning of each five year period. Graphs of the total added cost streams for each alternative at existing mills are shown in Exhibits 7-8A through 7-8E.

Examination of Exhibits 7-7A through 7-7E shows that the total added cost stream for final cover under the 20 year assumption sums to zero, when no discount rate is applied.

EXHIBIT 7-7(A):

COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1990

(millions 1985 dollars)

(20 year baseline)

	baseline				1990				added cost			
PERIOD	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL
1986-90	0	0	0	0	0	72	0	72	0	72	0	72
1991-95	0	0	0	0	658	72	0	730	658	72	0	730
1996-00	0	0	0	0	0	54	0	54	0	54	0	54
2001-05	0	0	0	0	0	0	0	0	0	0	0	0
2006-10	88	0	0	88	0	0	0	0	-88	0	0	-88
2011-15	439	0	0	439	0	0	0	0	-439	0	0	-439
2016-20	7	0	0	7	0	0	0	0	-7	0	0	-7
2021-25	41	0	0	41	0	0	0	0	-41	0	0	-41
2026-30	83	0	0	83	0	0	0	0	-83	0	0	-83
2031-35	0	0	0	0	0	0	0	0	0	0	0	0
2036-40	0	0	0	0	0	0	0	0	0	0	0	0
2041-45	0	0	0	0	0	0	0	0	0	0	0	0
2046-50	0	0	0	0	0	0	0	0	0	0	0	0
2051-55	0	0	0	0	0	0	0	0	0	0	0	0
2056-60	0	0	0	0	0	0	0	0	0	0	0	0
2061-65	0	0	0	0	0	0	0	0	0	0	0	0
2066-70	0	0	0	0	0	0	0	0	0	0	0	0
2071-75	0	0	0	0	0	0	0	0	0	0	0	0
2076-80	0	0	0	0	0	0	0	0	0	0	0	0
2081-85	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	658	0	0	658	658	199	0	856	0	199	0	199
PV(1%)	504	0	0	504	626	190	0	816	122	190	0	312
PV(5%)	184	0	0	184	515	162	0	677	332	162	0	494
PV(10%)	57	0	0	57	408	138	0	546	351	138	0	489

EXHIBIT 7-7(B):
COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1995

(millions 1985 dollars)

(20 year baseline)

	baseline				1995				added cost			
PERIOD	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL
1986-90	0	0	0	0	0	0	0	0	0	0	0	0
1991-95	0	0	0	0	0	72	0	72	0	72	0	72
1996-00	0	0	0	0	658	54	0	712	658	54	0	712
2001-05	0	0	0	0	0	0	0	0	0	0	0	0
2006-10	88	0	0	88	0	0	0	0	-88	0	0	-88
2011-15	439	0	0	439	0	0	0	0	-439	0	0	-439
2016-20	7	0	0	7	0	0	0	0	-7	0	0	-7
2021-25	41	0	0	41	0	0	0	0	-41	0	0	-41
2026-30	83	0	0	83	0	0	0	0	-83	0	0	-83
2031-35	0	0	0	0	0	0	0	0	0	0	0	0
2036-40	0	0	0	0	0	0	0	0	0	0	0	0
2041-45	0	0	0	0	0	0	0	0	0	0	0	0
2046-50	0	0	0	0	0	0	0	0	0	0	0	0
2051-55	0	0	0	0	0	0	0	0	0	0	0	0
2056-60	0	0	0	0	0	0	0	0	0	0	0	0
2061-65	0	0	0	0	0	0	0	0	0	0	0	0
2066-70	0	0	0	0	0	0	0	0	0	0	0	0
2071-75	0	0	0	0	0	0	0	0	0	0	0	0
2076-80	0	0	0	0	0	0	0	0	0	0	0	0
2081-85	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	658	0	0	658	658	126	0	784	0	126	0	126
PV(1%)	504	0	0	504	595	118	0	713	91	118	0	209
PV(5%)	184	0	0	184	404	90	0	494	220	90	0	310
PV(10%)	57	0	0	57	254	66	0	319	196	66	0	262

EXHIBIT 7-7(C):

COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS

AT EXISTING URANIUM MILLS BY 2000

(millions 1985 dollars)

(20 year baseline)

	baseline				2000				added cost			
PERIOD	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL
1986-90	0	0	0	0	0	0	0	0	0	0	0	0
1991-95	0	0	0	0	0	0	0	0	0	0	0	0
1996-00	0	0	0	0	0	54	0	54	0	54	0	54
2001-05	0	0	0	0	658	0	0	658	658	0	0	658
2006-10	88	0	0	88	0	0	0	0	-88	0	0	-88
2011-15	439	0	0	439	0	0	0	0	-439	0	0	-439
2016-20	7	0	0	7	0	0	0	0	-7	0	0	-7
2021-25	41	0	0	41	0	0	0	0	-41	0	0	-41
2026-30	83	0	0	83	0	0	0	0	-83	0	0	-83
2031-35	0	0	0	0	0	0	0	0	0	0	0	0
2036-40	0	0	0	0	0	0	0	0	0	0	0	0
2041-45	0	0	0	0	0	0	0	0	0	0	0	0
2046-50	0	0	0	0	0	0	0	0	0	0	0	0
2051-55	0	0	0	0	0	0	0	0	0	0	0	0
2056-60	0	0	0	0	0	0	0	0	0	0	0	0
2061-65	0	0	0	0	0	0	0	0	0	0	0	0
2066-70	0	0	0	0	0	0	0	0	0	0	0	0
2071-75	0	0	0	0	0	0	0	0	0	0	0	0
2076-80	0	0	0	0	0	0	0	0	0	0	0	0
2081-85	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	658	0	0	658	658	54	0	712	0	54	0	54
PV(1%)	504	0	0	504	566	49	0	615	62	49	0	111
PV(5%)	184	0	0	184	316	33	0	350	133	33	0	166
PV(10%)	57	0	0	57	157	21	0	178	100	21	0	121

EXHIBIT 7-7(D):

COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2005

(millions 1985 dollars)

(20 year baseline)

	baseline				2005				added cost			
PERIOD	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL
1986-90	0	0	0	0	0	0	0	0	0	0	0	0
1991-95	0	0	0	0	0	0	0	0	0	0	0	0
1996-00	0	0	0	0	0	0	0	0	0	0	0	0
2001-05	0	0	0	0	0	0	0	0	0	0	0	0
2006-10	88	0	0	88	658	0	0	658	570	0	0	570
2011-15	439	0	0	439	0	0	0	0	-439	0	0	-439
2016-20	7	0	0	7	0	0	0	0	-7	0	0	-7
2021-25	41	0	0	41	0	0	0	0	-41	0	0	-41
2026-30	83	0	0	83	0	0	0	0	-83	0	0	-83
2031-35	0	0	0	0	0	0	0	0	0	0	0	0
2036-40	0	0	0	0	0	0	0	0	0	0	0	0
2041-45	0	0	0	0	0	0	0	0	0	0	0	0
2046-50	0	0	0	0	0	0	0	0	0	0	0	0
2051-55	0	0	0	0	0	0	0	0	0	0	0	0
2056-60	0	0	0	0	0	0	0	0	0	0	0	0
2061-65	0	0	0	0	0	0	0	0	0	0	0	0
2066-70	0	0	0	0	0	0	0	0	0	0	0	0
2071-75	0	0	0	0	0	0	0	0	0	0	0	0
2076-80	0	0	0	0	0	0	0	0	0	0	0	0
2081-85	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	658	0	0	658	658	0	0	658	0	0	0	0
PV(1%)	504	0	0	504	539	0	0	539	35	0	0	35
PV(5%)	184	0	0	184	248	0	0	248	64	0	0	64
PV(10%)	57	0	0	57	98	0	0	98	40	0	0	40

EXHIBIT 7-7(E):

COST OF INTERIM COVER AT EXISTING URANIUM MILLS

(millions of 1985 dollars)

(20 year baseline)

	baseline				INTERIM ONLY				added cost			
PERIOD	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL	FINAL COVER	REPLACE MENT	INTERIM COVER	TOTAL
1986-90	0	0	0	0	0	0	21	21	0	0	21	21
1991-95	0	0	0	0	0	0	68	68	0	0	68	68
1996-00	0	0	0	0	0	0	32	32	0	0	32	32
2001-05	0	0	0	0	0	0	46	46	0	0	46	46
2006-10	88	0	0	88	88	0	30	118	0	0	30	30
2011-15	439	0	0	439	439	0	5	444	0	0	5	5
2016-20	7	0	0	7	7	0	5	12	0	0	5	5
2021-25	41	0	0	41	41	0	3	44	0	0	3	3
2026-30	83	0	0	83	83	0	0	83	0	0	0	0
2031-35	0	0	0	0	0	0	0	0	0	0	0	0
2036-40	0	0	0	0	0	0	0	0	0	0	0	0
2041-45	0	0	0	0	0	0	0	0	0	0	0	0
2046-50	0	0	0	0	0	0	0	0	0	0	0	0
2051-55	0	0	0	0	0	0	0	0	0	0	0	0
2056-60	0	0	0	0	0	0	0	0	0	0	0	0
2061-65	0	0	0	0	0	0	0	0	0	0	0	0
2066-70	0	0	0	0	0	0	0	0	0	0	0	0
2071-75	0	0	0	0	0	0	0	0	0	0	0	0
2076-80	0	0	0	0	0	0	0	0	0	0	0	0
2081-85	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	658	0	0	658	658	0	211	869	0	0	211	211
PV(1%)	504	0	0	504	504	0	189	693	0	0	189	189
PV(5%)	184	0	0	184	184	0	131	315	0	0	131	131
PV(10%)	57	0	0	57	57	0	92	150	0	0	92	92

EXHIBIT 7-8(A):

GRAPH OF ADDITIONAL COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1990

(20 year baseline)

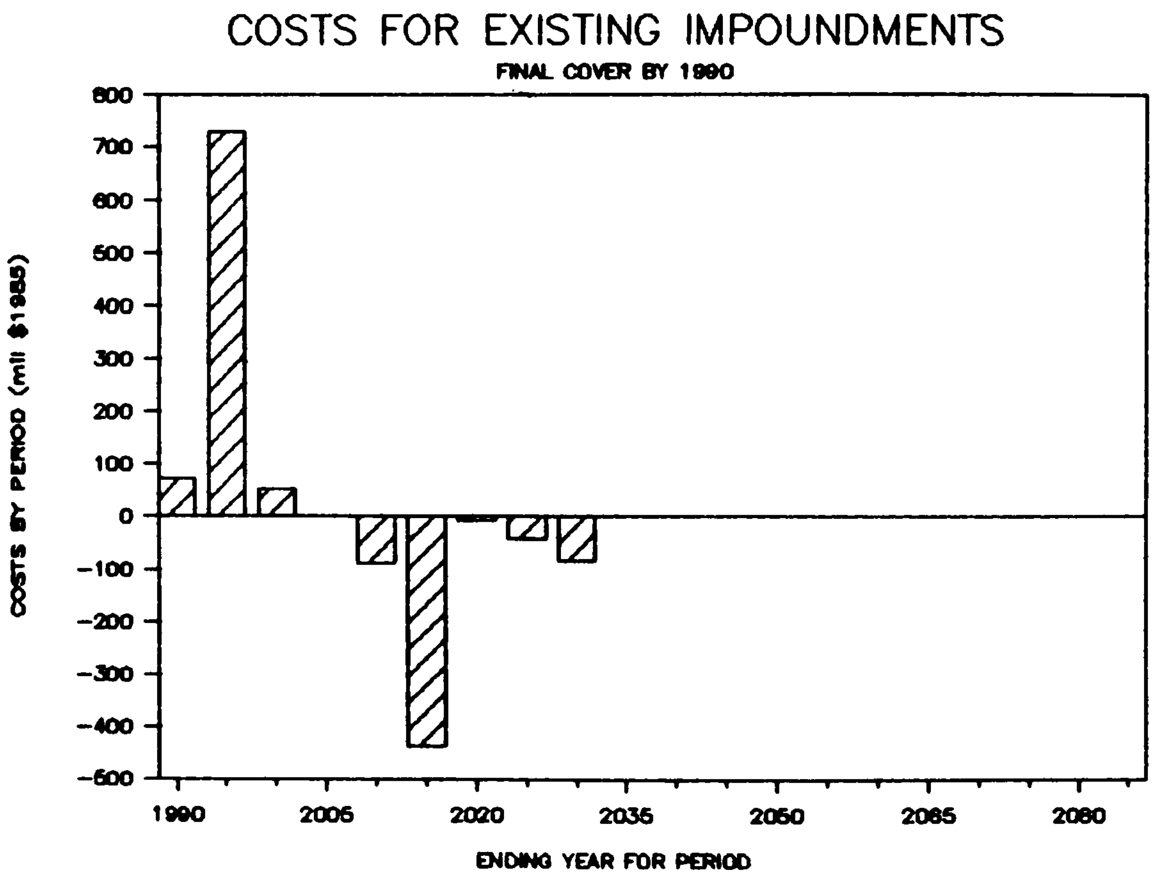


EXHIBIT 7-8(B):

GRAPH OF ADDITIONAL COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1995

(20 year baseline)

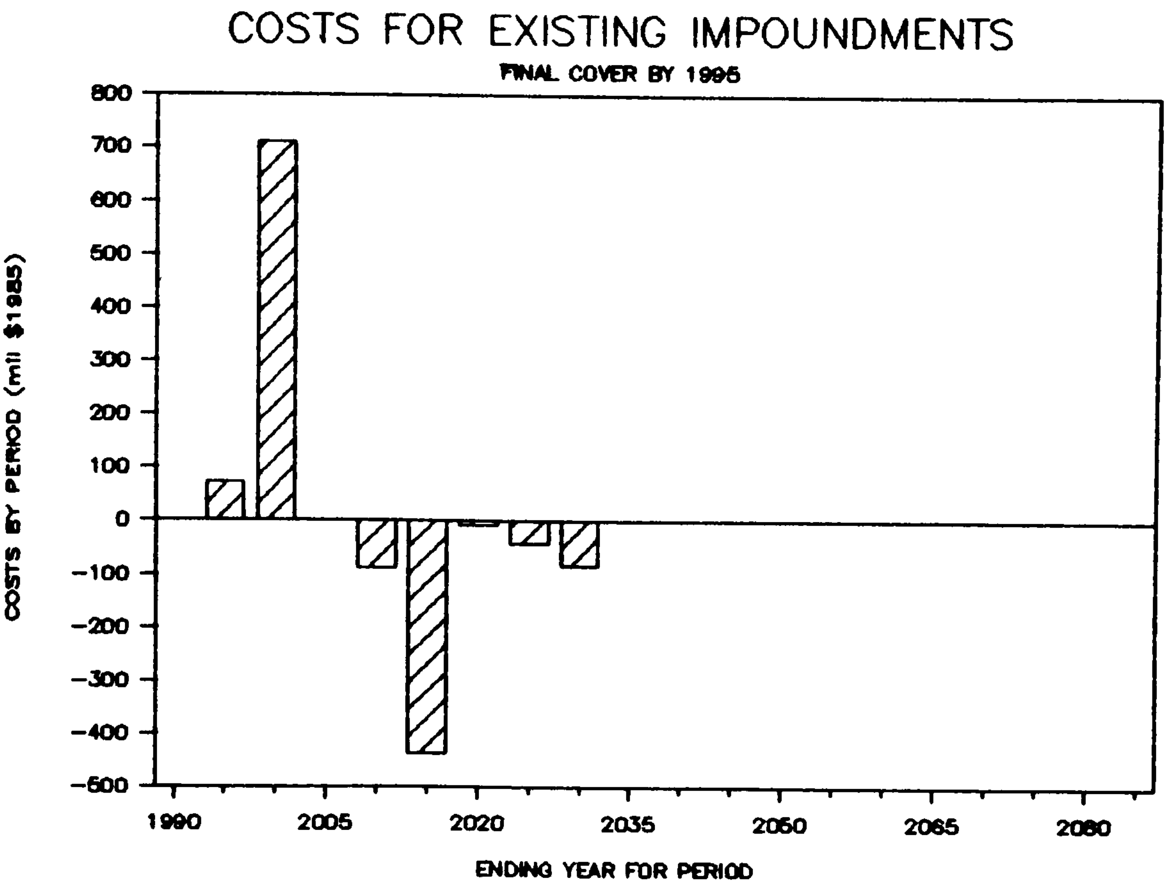


EXHIBIT 7-8(C):

GRAPH OF ADDITIONAL COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2000

(20 year baseline)

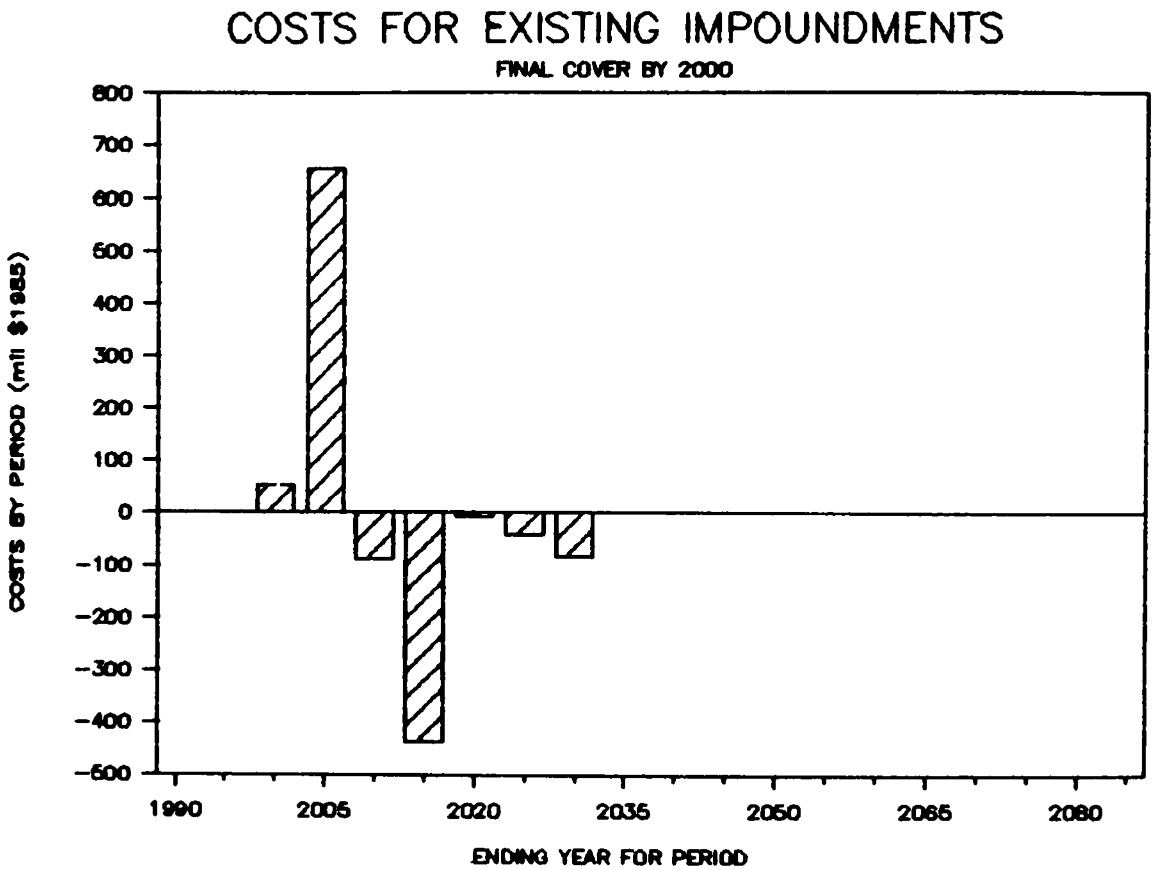


EXHIBIT 7-8(D):

GRAPH OF ADDITIONAL COST OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2005

(20 year baseline)

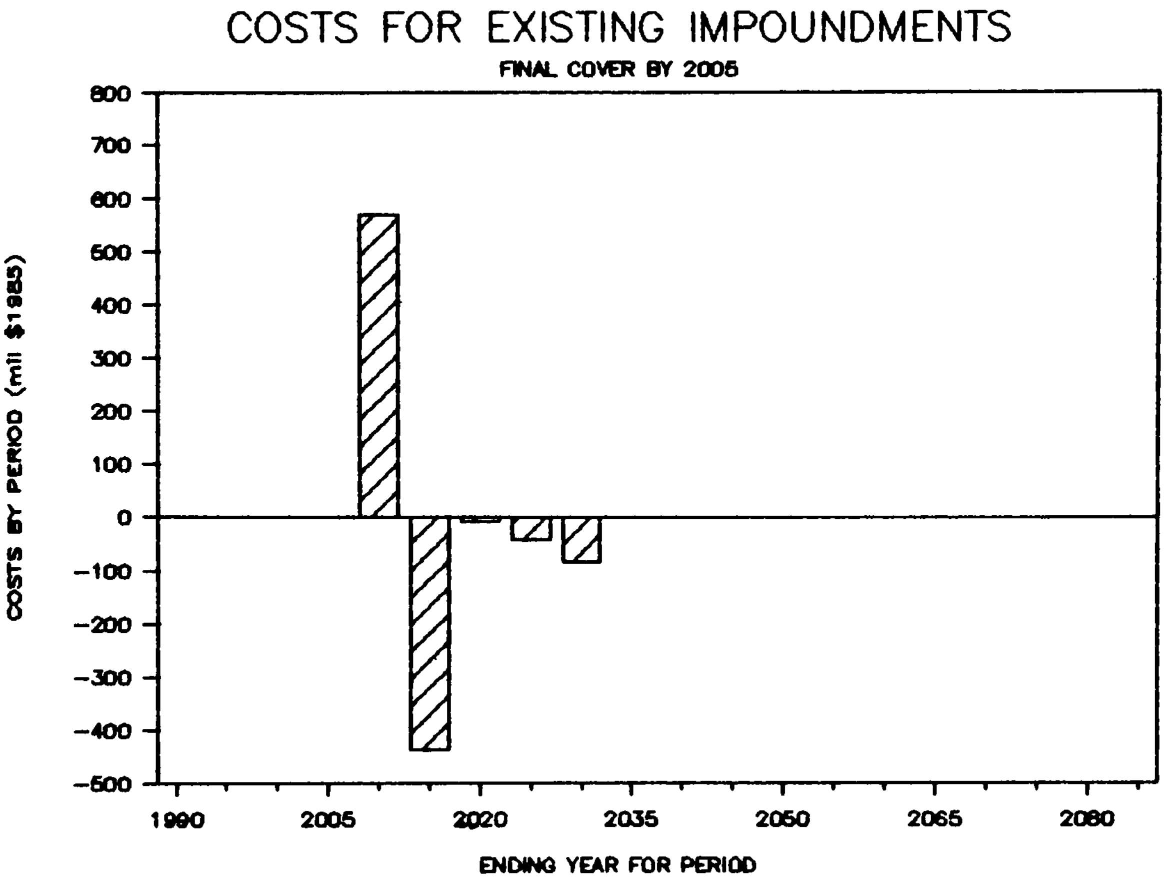
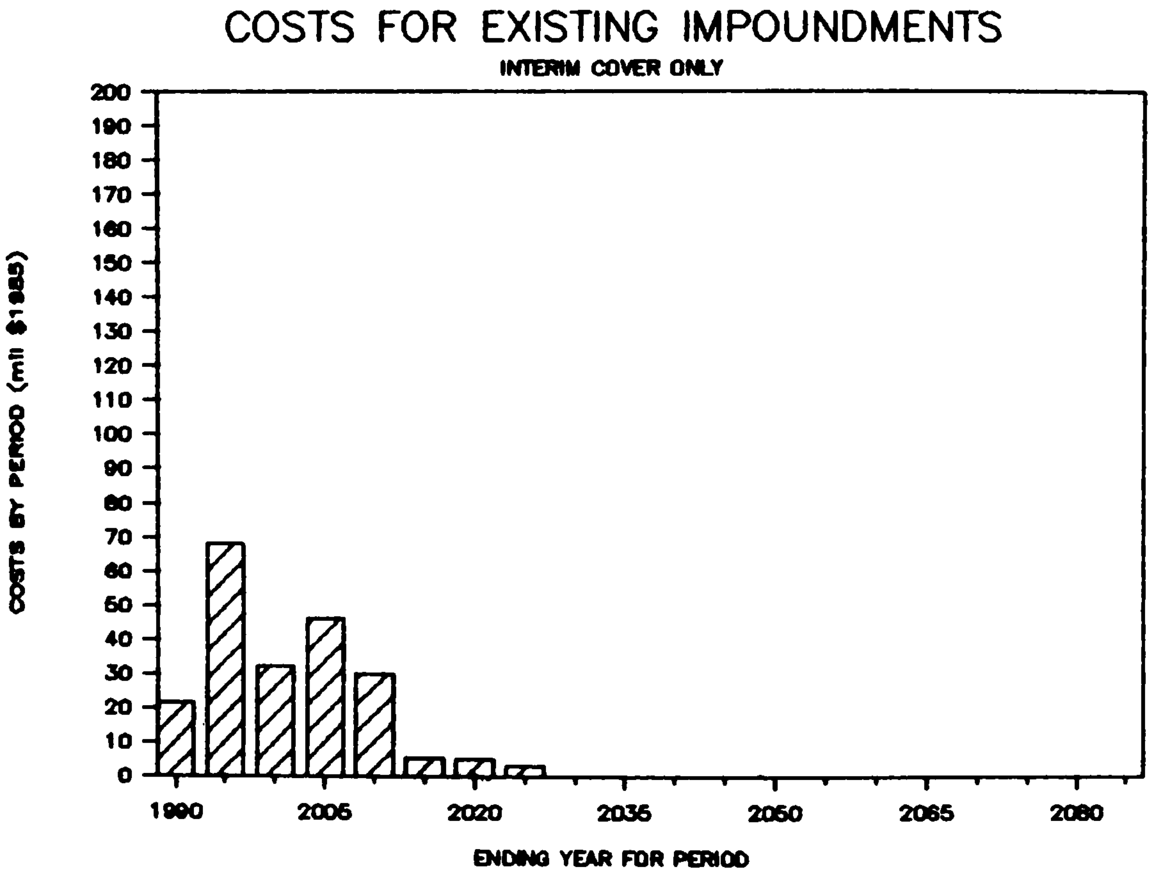


EXHIBIT 7-8(E):

GRAPH OF ADDITIONAL COST OF INTERIM COVER

AT EXISTING URANIUM MILLS

(20 year baseline)



However, the present value cost of final cover is positive for all discount rates greater than zero. This unusual result also occurs in the 40 year analysis and was discussed in Section 6.3.3.

The detailed results for the 20 year analysis presented in Exhibits 7-7 are summarized in Exhibit 7-9. The summary table shows the present value of the total social costs incurred by requiring the alternative work practices at existing mills. The present value cost of required expenditures for each cost category and total costs at 5 percent and 10 percent discount rates are shown for each alternative, where applicable. Alternatives which require final cover before 2005 have costs for replacement capacity, while the other alternatives do not require replacement of existing disposal capacity due to assumption that all existing mills cease operations by the year 2000.

Comparison of Exhibit 7-9 with the 40 year baseline results presented in Exhibit 6-19 shows that the change to a 20 year baseline assumption reduces the values of type 2 costs for final stabilization. This reduction occurs because these type 2 costs are moved up in time by 20 fewer years, resulting in a smaller opportunity cost. Type 1 costs for interim cover only are also reduced due to the shorter period of required maintenance on these interim covers. These reductions in present value costs are more substantial at a 5 percent discount rate compared to a 10 percent rate. Comparison with the 40 year baseline results presented in Exhibit 6-19 shows that the opportunity cost of earlier final stabilization is lower under the 20 year baseline for alternatives 1 through 4. The cost of alternative 5, interim cover only, is also lower. At a 5 percent discount rate, total costs of alternative 1 are reduced 19 percent from the 40 year results (See Exhibit 6-19). At a 10 percent rate of discount, costs are reduced only 9 percent. The equivalent reductions in total costs for alternatives 2, 3, and 4, respectively, are: 27 percent, 41 percent, and 76 percent at a 5 percent rate of discount; and 16 percent, 29 percent and 45 percent at a 10 percent discount rate. Although the cost of each of the alternatives 1 through 4 are reduced by adopting the 20 year baseline assumption over the 40 year baseline assumption, alternatives 2, 3 and 4 are reduced by succeedingly larger proportions. This is due to the fact that alternatives which require later dates of final stabilization have a higher percentage of type 2 costs than alternatives with earlier dates.

Costs for interim cover only at existing impoundments, alternative 5, are also reduced by the change to a 20 year baseline. As noted above, this is due to the shorter

EXHIBIT 7-9:

PRESENT VALUE COSTS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS, FOR VARIOUS ALTERNATIVES

(20 year baseline)

Control Alternative	Present Value Cost (millions of 1985 dollars) 5 Percent Discount Type 2[a] Final Stabilization	5 Percent Discount Type 1[b] Replacement Impoundments	5 Percent Discount Type 1 Interim Stabilization	5 Percent Discount Total Cost	10 Percent Discount Type 2 Final Stabilization	10 Percent Discount Type 1 Replacement Impoundments	10 Percent Discount Type 1 Interim Stabilization	10 Percent Discount Total Cost
1. Require new technology now, achieve final stabilization by 1990.	332	162	NA	494	351	138	NA	489
2. Require new technology by 1990, achieve final stabilization by 1995.	220	90	NA	310	196	66	NA	262
3. Require new technology by 1995, achieve final stabilization by 2000.	133	33	NA	166	100	21	NA	121
4. Require new technology by 2000, achieve final stabilization by 2005.	64	NA	NA	64	40	NA	NA	40
5. Interim stabilization only (1 meter)	NA	NA	131	131	NA	NA	92	92

[a]Type 2 costs represents the time value or the opportunity cost of stabilizing an impoundment sooner than it would have been stabilized in the absence of EPA action.

[b]Type 1 costs are due to the loss of disposal capacity in impoundments at existing mills and the nonrecoverable cost of interim stabilization.

Note: Detail may not add to totals due to independent rounding.

maintenance period required in the 20 year scenario. Costs at a 5 percent discount fall 13 percent, when compared to the equivalent cost under the 40 year assumption shown in Exhibit 6-19. At a 10 percent discount rate, the change is less, only 5 percent.

7.4 TOTAL BENEFITS ESTIMATES — EXISTING MILLS

The benefits of reduced radon-222 emissions resulting from adoption of the recommended work practices at existing licensed uranium mills were presented in Exhibit 6-9. These benefits occur due to earlier final stabilization of existing impoundments at current mill sites, and due to reduced operating emissions during disposal of future tailings generated at these mills. The magnitude of the estimated benefits presented in Chapter 6 is strongly affected by the baseline assumption that existing impoundments will remain in a dry, uncovered status for 40 years before final stabilization. In this section a sensitivity analysis is conducted using a 20 year baseline assumption.

As for the 40 year scenario, estimates of baseline and avoided fatal lung cancers due to radon-222 emissions at existing mills under the 20 year baseline are presented in Exhibits 7-10A through 7-10E for each alternative date of final stabilization at existing impoundments and for interim cover only. The avoided fatalities are reported in five-year periods for the local area (0-5 kilometers), the local region (5-80 kilometers), and for the rest of the nation. These estimates were developed by summing the site-specific health effects estimats presented in Exhibit 6-9, given the time pattern of future operations of existing mills implied by the baseline low-production scenario.

For alternatives which require final cover before 2005, the early closure of existing impoundments requires an earlier dry-out period which would not occur in the absence of this regulation. The higher emissions of these impoundments while drying cause negative benefits in the period preceding the date of final stabilization. These alternatives also require the construction of additional replacement impoundments, causing small negative benefits in the period after 2045. These effects were also encountered in the 40 year analysis of Chapter 6. The benefits at existing mills under the 20 year scenario are graphed in Exhibits 7-11A through 7-11E.

EXHIBIT 7-10(A):
BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS
AT EXISTING URANIUM MILLS BY 1990
(committed fatal cancers)
(20 year baseline)

	baseline				Avoided Fatalities 1990			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.7	5.4	10.4	16.5	-0.1	-0.5	-1.0	-1.6
1991-95	0.8	6.8	12.9	20.5	0.8	6.4	12.2	19.4
1996-00	0.8	6.8	13.3	20.9	0.8	6.5	12.7	19.9
2001-05	0.9	7.2	14.2	22.3	0.8	6.9	13.6	21.4
2006-10	0.8	6.2	12.4	19.4	0.8	5.9	11.8	18.4
2011-15	0.2	1.6	3.6	5.4	0.1	1.3	3.0	4.5
2016-20	0.2	1.6	3.4	5.2	0.1	1.3	2.8	4.2
2021-25	0.2	1.5	2.4	4.1	0.1	1.2	1.8	3.1
2026-30	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2031-35	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2036-40	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2041-45	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2046-50	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2051-55	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2056-60	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2061-65	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2066-70	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2071-75	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2076-80	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2081-85	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
TOTAL	4.9	40.3	78.7	124.0	3.4	28.5	55.8	87.7

EXHIBIT 7-10(B):

BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1995

(committed fatal cancers)

(20 year baseline)

	baseline				Avoided Fatalities 1995			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.7	5.4	10.4	16.5	0.0	0.0	0.0	0.0
1991-95	0.8	6.8	12.9	20.5	-0.1	-0.5	-1.0	-1.6
1996-00	0.8	6.8	13.3	20.9	0.8	6.5	12.7	20.0
2001-05	0.9	7.2	14.2	22.3	0.8	7.0	13.6	21.4
2006-10	0.8	6.2	12.4	19.4	0.8	5.9	11.8	18.5
2011-15	0.2	1.6	3.6	5.4	0.1	1.3	3.0	4.5
2016-20	0.2	1.6	3.4	5.2	0.1	1.3	2.8	4.3
2021-25	0.2	1.5	2.4	4.1	0.1	1.2	1.8	3.1
2026-30	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2031-35	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2036-40	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2041-45	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2046-50	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2051-55	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2056-60	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2061-65	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2066-70	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2071-75	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2076-80	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2081-85	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
TOTAL	4.9	40.3	78.7	124.0	2.7	22.3	43.9	68.8

EXHIBIT 7-10(C):

BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2000

(committed fatal cancers)

(20 year baseline)

	baseline				Avoided Fatalities 2000			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.7	5.4	10.4	16.5	0.0	0.0	0.0	0.0
1991-95	0.8	6.8	12.9	20.5	0.0	0.0	0.0	0.0
1996-00	0.8	6.8	13.3	20.9	-0.1	-0.4	-0.5	-1.1
2001-05	0.9	7.2	14.2	22.3	0.8	7.0	13.6	21.4
2006-10	0.8	6.2	12.4	19.4	0.8	5.9	11.9	18.5
2011-15	0.2	1.6	3.6	5.4	0.2	1.3	3.0	4.5
2016-20	0.2	1.6	3.4	5.2	0.1	1.3	2.8	4.3
2021-25	0.2	1.5	2.4	4.1	0.1	1.2	1.8	3.2
2026-30	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2031-35	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2036-40	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2041-45	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2046-50	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2051-55	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2056-60	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2061-65	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2066-70	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2071-75	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2076-80	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
2081-85	0.0	0.3	0.5	0.8	-0.0	-0.0	-0.1	-0.1
TOTAL	4.9	40.3	78.7	124.0	1.9	16.0	31.9	49.8

EXHIBIT 7-10(D):

BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2005

(20 year baseline)

	Avoided Fatalities							
	baseline				2005			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.7	5.4	10.4	16.5	0.0	0.0	0.0	0.0
1991-95	0.8	6.8	12.9	20.5	0.0	0.0	0.0	0.0
1996-00	0.8	6.8	13.3	20.9	0.0	0.0	0.0	0.0
2001-05	0.9	7.2	14.2	22.3	0.0	0.0	0.0	0.0
2006-10	0.8	6.2	12.4	19.4	0.8	5.9	11.9	18.6
2011-15	0.2	1.6	3.6	5.4	0.2	1.4	3.1	4.6
2016-20	0.2	1.6	3.4	5.2	0.1	1.4	2.9	4.4
2021-25	0.2	1.5	2.4	4.1	0.1	1.3	1.8	3.3
2026-30	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2031-35	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2036-40	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2041-45	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2046-50	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2051-55	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2056-60	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2061-65	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2066-70	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2071-75	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2076-80	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2081-85	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
TOTAL	4.9	40.3	78.7	124.0	1.2	9.9	19.7	30.8

EXHIBIT 7-10(E):

BENEFITS OF INTERIM STABILIZATION

AT EXISTING URANIUM MILLS

(20 year baseline)

Avoided Fatalities

	baseline				INTERIM ONLY			
PERIOD	0-5KM	5-80KM	REST OF NATION	TOTAL	0-5KM	5-80KM	REST OF NATION	TOTAL
1986-90	0.7	5.4	10.4	16.5	0.1	0.7	1.1	1.9
1991-95	0.8	6.8	12.9	20.5	0.3	2.1	3.8	6.2
1996-00	0.8	6.8	13.3	20.9	0.2	1.4	2.8	4.3
2001-05	0.9	7.2	14.2	22.3	0.3	2.6	5.3	8.2
2006-10	0.8	6.2	12.4	19.4	0.3	2.5	5.0	7.8
2011-15	0.2	1.6	3.6	5.4	0.1	0.8	1.8	2.8
2016-20	0.2	1.6	3.4	5.2	0.1	0.8	1.7	2.6
2021-25	0.2	1.5	2.4	4.1	0.1	0.7	1.1	1.9
2026-30	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2031-35	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2036-40	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2041-45	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2046-50	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2051-55	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2056-60	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2061-65	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2066-70	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2071-75	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2076-80	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
2081-85	0.0	0.3	0.5	0.8	0.0	0.0	0.0	0.0
TOTAL	4.9	40.3	78.7	124.0	1.5	11.6	22.7	35.8

EXHIBIT 7-11(A):

GRAPH OF BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1990

(20 year baseline)

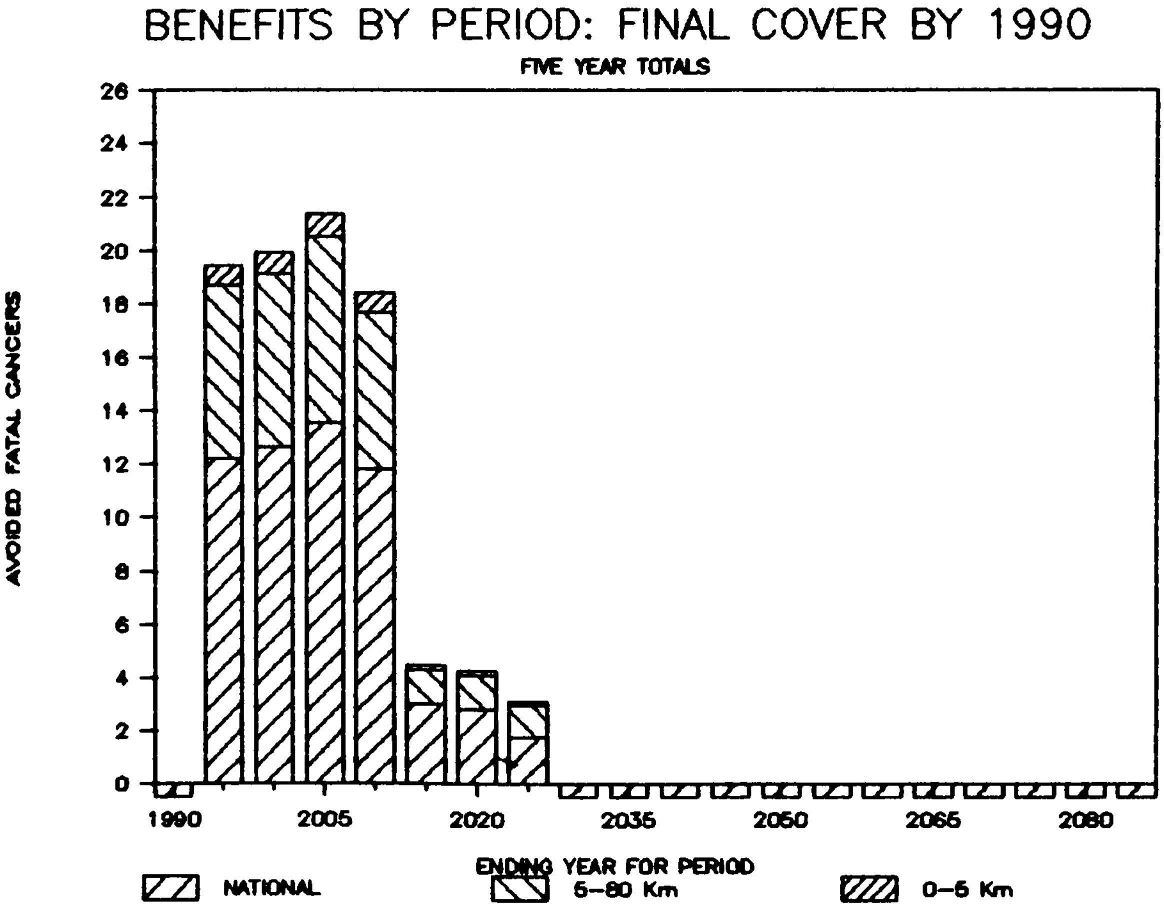


EXHIBIT 7-11(B):

GRAPH OF BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 1995

(20 year baseline)

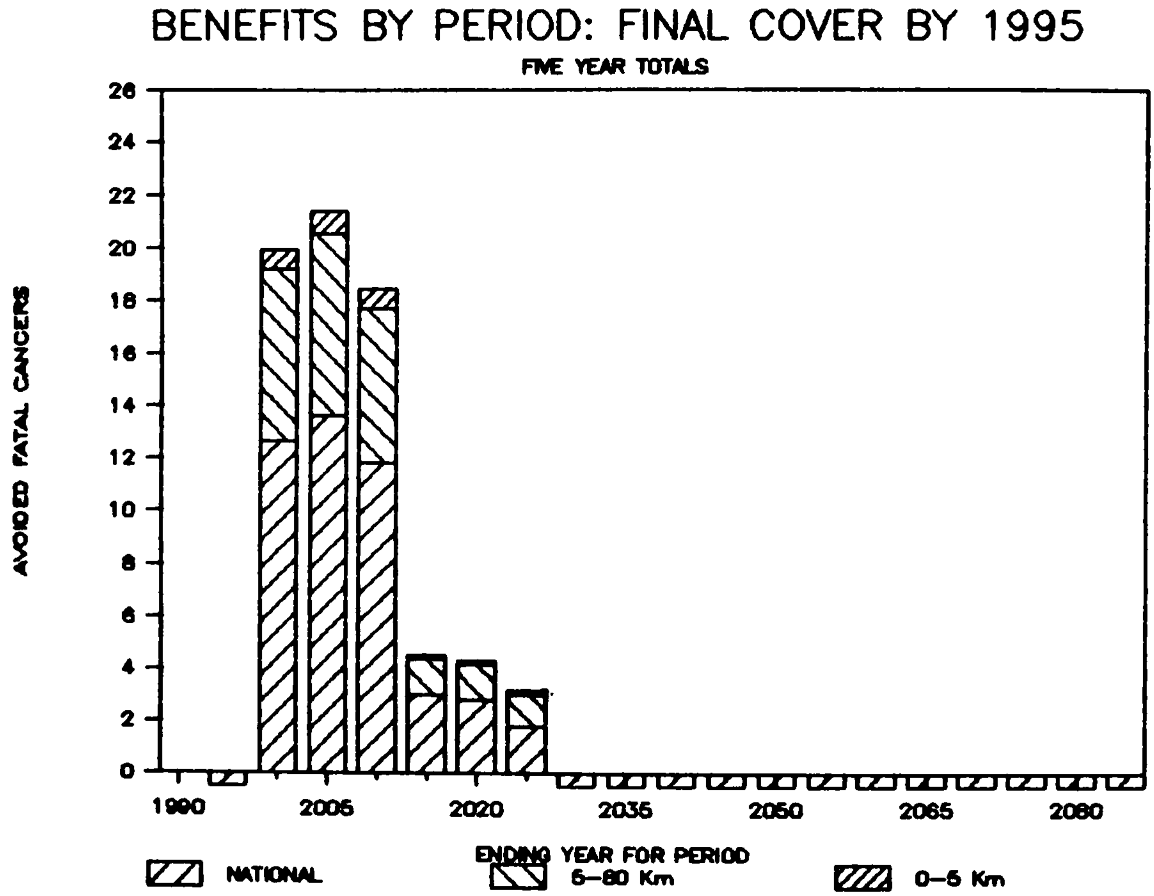


EXHIBIT 7-11(C):

GRAPH OF BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2000

(20 year baseline)

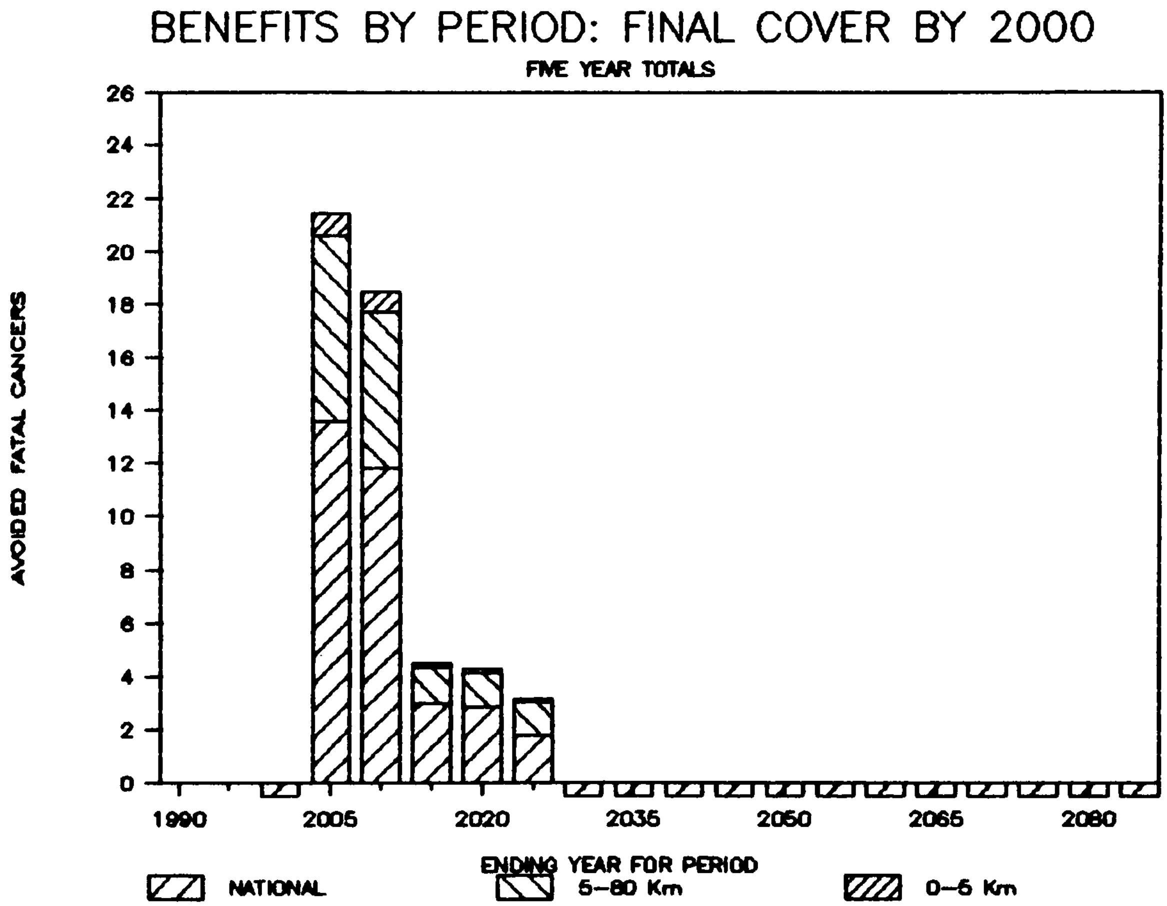


EXHIBIT 7-11(D):

GRAPH OF BENEFITS OF ACHIEVING FINAL STABILIZATION OF IMPOUNDMENTS AT EXISTING URANIUM MILLS BY 2005

(20 year baseline)

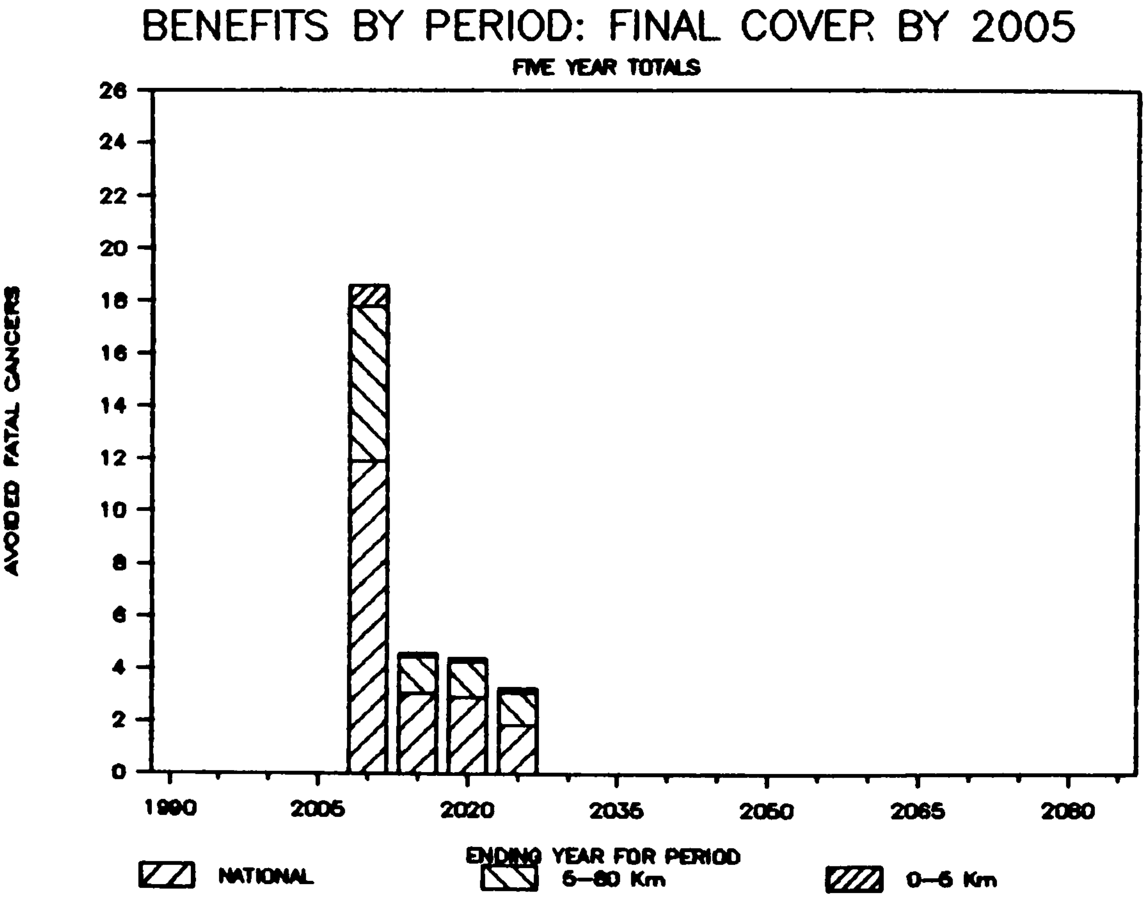


EXHIBIT 7-11(E):

GRAPH OF BENEFITS OF INTERIM STABILIZATION

AT EXISTING URANIUM MILLS

(20 year baseline)

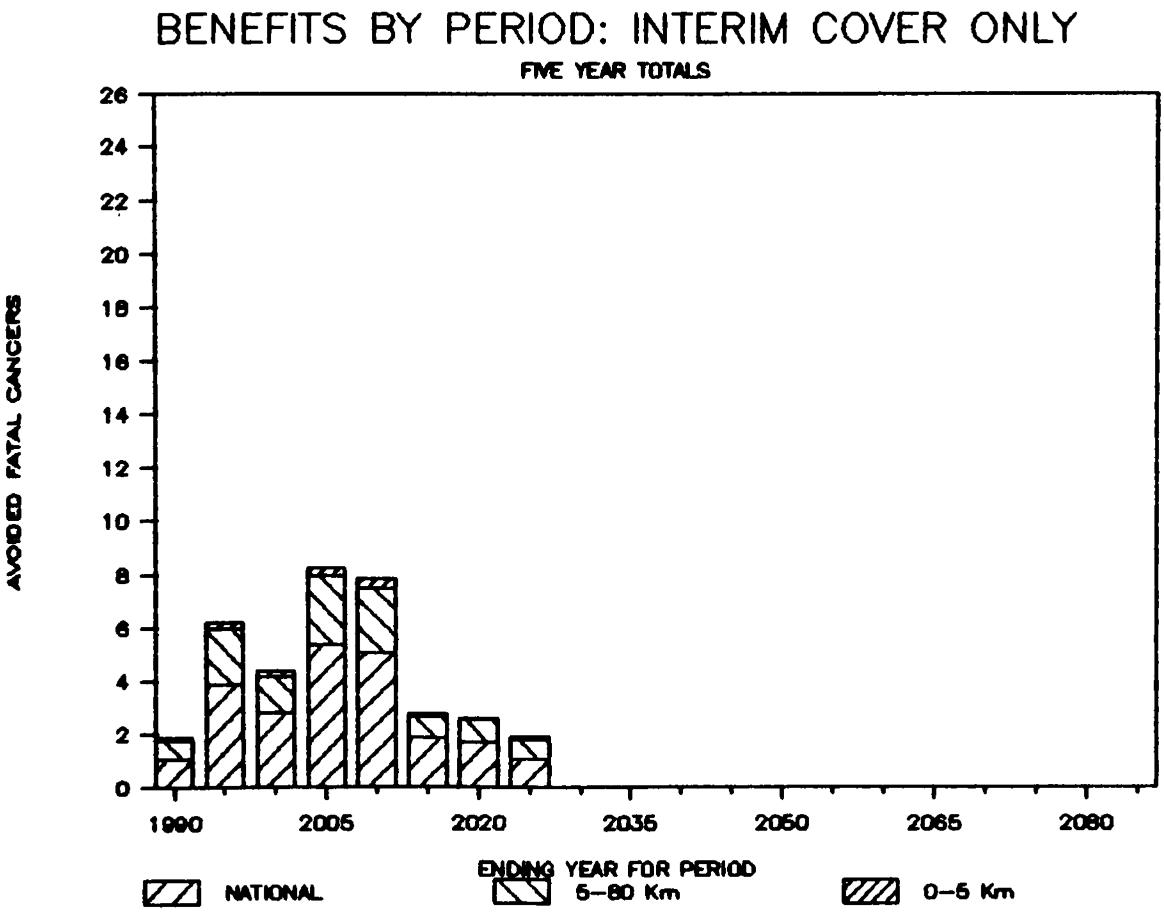


Exhibit 7-12 summarizes the estimated benefits of each alternative. In this exhibit, avoided fatalities in the local, regional, and rest of nation categories are compared for each alternative. Significant reductions in baseline fatal cancer incidence rates are also achievable in the 20 year scenario by requiring the recommended work practices at all existing and future uranium mills, beginning now or at some near time in the future. The percent of baseline fatal cancers avoided by the alternatives in the 40 year scenario ranged from 36 percent for interim cover only to 83 percent for final stabilization by 1990 (See Exhibit 6-22). In the 20 year scenario, baseline fatalities are significantly reduced due to the shorter period of emissions from dry impoundments after they are no longer used. However, the efficiency of the alternatives in mitigating the baseline health effects ranges from 25 percent for alternative 4 to 70 percent for alternative 1. This range of effectiveness is approximately 10 percentage points lower in the 20 year scenario than in the 40 year scenario.

EXHIBIT 7-12:
FATALITIES AVOIDED BY ALTERNATIVE WORK PRACTICES AT EXISTING MILLS, BY YEAR OF FINAL STABILIZATION

(20 year baseline)

Control Alternative	0-5Km		5-80 Km		Rest of Nation		Total	
	Avoided Fatalities	Percent Avoided	Avoided Fatalities	Percent Avoided	Avoided Fatalities	Percent Avoided	Avoided Fatalities	Percent Avoided
1. Require new technology now, achieve final stabilization by 1990.	3	60%	29	73%	56	71%	88	70%
2. Require new technology by 1990, achieve final stabilization by 1995.	3	60%	22	55%	44	56%	69	55%
3. Require new technology by 1995, achieve final stabilization by 2000.	2	40%	16	40%	32	41%	50	40%
4. Require new technology by 2000, achieve final stabilization by 2005.	1	20%	10	25%	20	25%	31	25%
5. Interim stabilization only (1 meter)	2	40%	12	30%	23	29%	36	29%
6. Baseline Fatalities	5		40		79		125	

Note: Detail may not add to totals due to independent rounding.

CHAPTER 8:

SENSITIVITY ANALYSIS

The estimated costs and benefits of the alternative work practices presented in the previous sections were calculated for existing and future mills based on a set of assumptions which collectively form the reference case. The sensitivity of the estimated costs and benefits to a change in the 40 year reference case assumption was presented in Chapter 7 above. Other reference case assumptions to be examined include the low demand forecast which affects the number of mills in operation, the design type of future impoundments (whether above or below grade), and the severity of health effects resulting from radon-222 emissions from these impoundments. In this section, the sensitivity of the reference case cost and benefit estimates to a change in each of these assumptions is examined. The total cost estimates presented in Section 6.3 under the reference case set of assumptions are sensitive to changes in the number of operating mills, and the design type assumed for the impoundment. (The present value costs are also sensitive to the assumed discount rate. All results in the previous section were presented at a 5% and 10% real discount rate. This convention will be continued in the sensitivity analysis.) The estimated total benefits are sensitive to the number of operating mills and the number of fatal lung cancers expected from the radon-222 releases. The sensitivity analyses conducted in this section are summarized in Exhibit 8-1.

The sensitivity analyses are conducted by varying one assumption, while holding the other assumptions at the reference case value. This procedure measures the sensitivity of the estimated cost and benefit to changes in each assumption individually, and does not generate estimates for all possible combinations of values for the entire set of assumptions. The latter procedure is unmanageable due to the large number of possible combinations which can be constructed by considering all variations of each assumption simultaneously.

8.1 SENSITIVITY OF ESTIMATED COSTS TO ALTERNATIVE ASSUMPTIONS

Estimated total costs presented in Section 6.3 for existing and future mills were developed under the reference case set of assumptions shown in Exhibit 8-1. A

EXHIBIT 8-1:
SUMMARY OF SENSITIVITY ANALYSES FOR COSTS AND BENEFITS[a]

		Alternative Assumptions	
Type of Assumption	Reference Case	Costs	Benefits
1. Level of production	Low production	(a) High production	(a) High production
2. Design type	Below grade	(b) Partially below grade	N/A
3. Health effects factor	760 fatal cancers/ million-person-WLM	N/A	(c) 380 fatal cancers/million-person-WLM (d) 1520 fatal cancers/million-person-WLM

[a] The sensitivity analyses are based on the 40-year baseline case presented in Chapter 6. The sensitivity of changing the 40-year assumption to 20 years was presented in detail in Chapter 7.

summary of the estimated total costs for future mills was presented in Exhibit 6-12 using the 40-year baseline assumption, for each alternative work practice. A summary of estimated total costs at existing mills under the 40 year assumption was presented in Exhibit 6-19, for each of five alternatives. The sensitivity analysis presents results for these alternatives: cover by 1990, cover by 1995, cover by 2000, cover by 2005, and interim cover only. The summary total cost tables for new and existing mills are recalculated in this sensitivity analysis for each of these five alternatives, under each of the revised cost assumptions shown in Exhibit 8-1.

The revised summary total cost tables for future mills are shown in Exhibits 8-2A, and 8-2B for the high production, and partially below grade assumptions, respectively. For the continuous disposal partially-below grade sensitivity analysis, the single-cell design is used since this is the more economical option. Exhibits 8-3A, and 8-3B contain the revised summary total cost estimates for existing mills, under the same variations of the reference case assumptions which affect the cost estimates.

8.2 SENSITIVITY OF ESTIMATED BENEFITS TO ALTERNATIVE ASSUMPTIONS

Benefits resulting from the alternative work practices were presented in Section 6.3. These estimates were derived using the reference case set of assumptions shown in Exhibit 8-1. A summary of estimated total benefits of the alternative work practices at future mills was presented in Exhibit 6-15. A summary of estimated total benefits at existing mills was presented in Exhibit 6-22, for each of five alternatives. Recalculations of the estimated total benefits for the sensitivity analysis of these alternatives were based on the revised assumptions affecting benefits, as shown in Exhibit 8-1.

The revised summary total benefits tables for future mills are shown in Exhibits 8-4A, 8-4B, and 8-4C for the high production scenario, and the revised health-effects factors of 380 and 1520 fatal cancers per million-person-WLM, respectively. Revised total benefits tables for existing mills are presented in Exhibits 8-5A, 8-5B, and 8-5C.

EXHIBIT 8-2(A):

RESULTS OF COST SENSITIVITY ANALYSIS FOR FUTURE MILLS: HIGH PRODUCTION

(millions 1985 dollars)

Period	Single Cell - Cover in 5 Years		Phased Disposal		Continuous Disposal	
	Reference Case(*)	Alternative Case(**)	Reference Case	Alternative Case	Reference Case	Alternative Case
1986-90	0	0	0	0	0	0
1991-95	0	0	0	0	0	0
1996-00	0	0	0	0	0	0
2001-05	0	0	-164	-225	-123	-169
2006-10	0	0	95	118	129	167
2011-15	0	0	122	163	147	203
2016-20	0	0	-130	-193	-102	-143
2021-25	63	87	120	154	150	211
2026-30	8	16	136	222	168	281
2031-35	8	16	-116	165	-82	-99
2036-40	71	110	155	201	186	271
2041-45	16	39	136	268	171	341
2046-50	16	32	-97	-134	-64	-57
2051-55	79	133	152	232	189	312
2056-60	16	55	153	317	189	397
2061-65	-39	-39	-163	-186	-124	-105
2066-70	71	133	161	235	199	317
2071-75	16	55	163	338	199	418
2076-80	-47	-55	-168	-209	-132	-126
2081-85	71	118	155	210	191	296
Post-2085	-347	-700	-157	-213	-197	-295
TOTAL	0	0	553	1135	1092	2225
PV(1%)	105	210	353	695	681	1336
PV(5%)	26	44	22	38	95	161
PV(10%)	3.5	5.3	-13	-21	8.3	12.8

(*) Reference Case: Low Production
(**) Alternative Case: High Production

EXHIBIT 8-2(B):

RESULTS OF COST SENSITIVITY ANALYSIS FOR FUTURE MILLS: PARTIALLY BELOW GRADE DISPOSAL

(million of 1985 dollars)

Period	Single Cell - Cover in 5 Years		Phased Disposal		Continuous Disposal	
	Reference Case(*)	Alternative Case(**)	Reference Case	Alternative Case	Reference Case	Alternative Case
1986-90	0	0	0	0	0	0
1991-95	0	0	0	0	0	0
1996-00	0	0	0	0	0	0
2001-05	0	0	-164	-75	-123	-55
2006-10	0	0	95	86	129	93
2011-15	0	0	122	113	147	105
2016-20	0	0	-130	-28	-102	-37
2021-25	63	82	120	121	150	110
2026-30	8	10	136	135	168	123
2031-35	8	10	-116	-6	-82	-19
2036-40	71	92	155	153	186	135
2041-45	16	20	136	145	171	128
2046-50	16	20	-97	12	-64	-7
2051-55	79	102	152	159	189	141
2056-60	16	21	153	161	189	141
2061-65	-39	-51	-163	-64	-124	-83
2066-70	71	92	161	165	199	143
2071-75	16	21	163	167	199	143
2076-80	-47	-61	-168	-70	-132	-94
2081-85	71	92	155	156	191	133
Post-2085	-347	-451	-157	-322	-197	-445
TOTAL	0	0	553	1010	1092	656
PV(1%)	105	136	353	677	681	520
PV(5%)	26	33	22	105	95	100
PV(10%)	3.5	4.5	-13	13	8.3	17

(*) Reference Case: Entirely below grade disposal
(**) Alternative Case: Partially below grade disposal

EXHIBIT 8-3(A):

RESULTS OF COST SENSITIVITY ANALYSIS AT EXISTING MILLS: HIGHER PRODUCTION

(millions 1985 dollars)

Period	Cover by 1990		Cover by 1995		Cover by 2000		Cover by 2005		Interim Only	
	Reference Case(*)	Alternative Case(**)	Reference Case	Alternative Case	Reference Case	Alternative Case	Reference Case	Alternative Case	Reference Case	Alternative Case
1986-90	72	72	0	0	0	0	0	0	21	21
1991-95	730	729	72	72	0	0	0	0	68	64
1996-00	54	72	712	729	54	72	0	0	32	31
2001-05	0	0	0	0	658	658	0	0	46	43
2006-10	0	0	0	0	0	0	658	657	35	38
2011-15	0	0	0	0	0	0	0	0	24	24
2016-20	0	0	0	0	0	0	0	0	24	24
2021-25	0	0	0	0	0	0	0	0	24	24
2026-30	-88	-88	-88	-88	-88	-88	-88	-88	19	19
2031-35	-439	-412	-439	-412	-439	-412	-439	-412	5	6
2036-40	-7	-7	-7	-7	-7	-7	-7	-7	5	6
2041-45	-41	-41	-41	-41	-41	-41	-41	-41	3	4
2046-50	-83	-109	-83	-109	-83	-109	-83	-109	0	0
2051-55	0	0	0	0	0	0	0	0	0	0
2056-60	0	0	0	0	0	0	0	0	0	0
2061-65	0	0	0	0	0	0	0	0	0	0
2066-70	0	0	0	0	0	0	0	0	0	0
2071-75	0	0	0	0	0	0	0	0	0	0
2076-80	0	0	0	0	0	0	0	0	0	0
2081-85	0	0	0	0	0	0	0	0	0	0
Post-2085	0	0	0	0	0	0	0	0	0	0
TOTAL	199	247	126	175	54	72	0	0	307	305
PV(1%)	403	427	300	325	202	222	126	134	258	255
PV(5%)	608	621	424	437	280	293	179	180	151	147
PV(10%)	538	545	311	318	170	177	89	90	97	94

(*) Reference Case: Low Production
(**) Alternative Case: Higher Production

EXHIBIT 8-3(B):

RESULTS OF COST SENSITIVITY ANALYSIS AT EXISTING MILLS: PARTIALLY BELOW GRADE DISPOSAL

(millions 1985 dollars)

Period	Cover by 1990		Cover by 1995		Cover by 2000		Cover by 2005[a]		Interim Only[a]	
	Reference Case(*)	Alternative Case(**)	Reference Case	Alternative Case	Reference Case	Alternative Case	Reference Case	Alternative Case	Reference Case	Alternative Case
1986-90	72	50	0	0	0	0	0	0	21	21
1991-95	730	707	72	50	0	0	0	0	68	68
1996-00	54	37	712	694	54	37	0	0	32	32
2001-05	0	0	0	0	658	658	0	0	46	46
2006-10	0	0	0	8	0	0	658	658	35	35
2011-15	0	0	0	8	0	0	0	0	24	24
2016-20	0	0	0	0	0	0	0	0	24	24
2021-25	0	0	0	0	0	0	0	0	24	24
2026-30	-88	-88	-88	-88	-88	-88	-88	-88	19	19
2031-35	-439	-439	-439	-439	-439	-439	-439	-439	5	5
2036-40	-7	-7	-7	-7	-7	-7	-7	-7	5	5
2041-45	-41	-41	-41	-41	-41	-41	-41	-41	3	3
2046-50	-83	-83	-83	-83	-83	-83	-83	-83	0	0
2051-55	0	0	0	0	0	0	0	0	0	0
2056-60	0	0	0	0	0	0	0	0	0	0
2061-65	0	0	0	0	0	0	0	0	0	0
2066-70	0	0	0	0	0	0	0	0	0	0
2071-75	0	0	0	0	0	0	0	0	0	0
2076-80	0	0	0	0	0	0	0	0	0	0
2081-85	0	0	0	0	0	0	0	0	0	0
Post-2085	0	0	0	0	0	0	0	0	0	0
TOTAL	199	137	126	87	54	37	0	0	308	308
PV(1%)	403	344	300	264	202	187	126	126	258	258
PV(5%)	608	558	424	397	280	270	179	179	151	151
PV(10%)	538	495	311	290	170	163	89	89	97	97

(*) Reference Case: Entirely below grade disposal
(**) Alternative Case: Partially below grade disposal

(a) No change in costs since new replacement impoundments are not required.

EXHIBIT 8-4(A):

RESULTS OF BENEFITS SENSITIVITY ANALYSIS AT FUTURE MILLS: HIGH PRODUCTION

(avoided fatal cancers)

Period	Single Cell - Cover in 5 Years: Reference Case(*)	Single Cell - Cover in 5 Years: Alternative Case(**)	Phased Disposal: Reference Case	Phased Disposal: Alternative Case	Continuous Disposal: Reference Case	Continuous Disposal: Alternative Case
1986-90	0.0	0.0	0.0	0.0	0.0	0.0
1991-95	0.0	0.0	0.0	0.0	0.0	0.0
1996-00	0.0	0.0	0.0	0.0	0.0	0.0
2001-05	0.0	0.0	0.1	0.1	0.2	0.3
2006-10	0.0	0.0	0.1	0.1	0.3	0.4
2011-15	0.0	0.0	0.1	0.1	0.3	0.4
2016-20	0.0	0.0	1.5	1.3	2.0	2.8
2021-25	3.0	4.1	3.2	2.9	3.5	5.1
2026-30	3.3	4.8	3.6	3.4	3.9	5.9
2031-35	3.7	5.5	5.4	5.2	6.0	9.2
2036-40	7.0	10.7	7.5	7.5	7.8	12.5
2041-45	7.8	12.5	8.2	8.6	8.6	14.2
2046-50	8.8	14.0	10.3	10.9	11.0	18.4
2051-55	12.2	20.3	12.7	13.8	13.1	22.7
2056-60	12.9	22.9	13.6	15.3	14.0	25.1
2061-65	11.1	21.0	13.0	15.6	13.7	26.0
2066-70	14.4	27.3	15.1	18.5	15.5	30.2
2071-75	15.2	29.9	15.8	19.9	16.3	32.4
2076-80	12.9	27.3	15.0	19.7	15.7	32.5
2081-85	16.3	32.8	16.9	22.1	17.4	36.0
Post-2085	123.1	242.0	126.1	249.0	127.1	252.0
TOTAL	251.3	476.0	268.2	510.4	276.3	527.0

(*) Reference Case: Low Production
(**) Alternative Case: High Production

EXHIBIT 8-4(B):

RESULTS OF BENEFITS SENSITIVITY ANALYSIS AT FUTURE MILLS: 380 FATAL CANCERS/MILLION-PERSON-WLM

(avoided fatal cancers)

Period	Single Cell - Cover in 5 Years		Phased Disposal		Continuous Disposal	
	Reference Case(*)	Alternative Case(**)	Reference Case	Alternative Case	Reference Case	Alternative Case
1986-90	0.0	0.0	0.0	0.0	0.0	0.0
1991-95	0.0	0.0	0.0	0.0	0.0	0.0
1996-00	0.0	0.0	0.0	0.0	0.0	0.0
2001-05	0.0	0.0	0.1	0.1	0.2	0.1
2006-10	0.0	0.0	0.1	0.1	0.3	.2
2011-15	0.0	0.0	0.1	0.1	0.3	.2
2016-20	0.0	0.0	1.5	0.7	2.0	1.0
2021-25	3.0	1.5	3.2	1.6	3.5	1.7
2026-30	3.3	1.6	3.6	1.8	3.9	1.9
2031-35	3.7	1.8	5.4	2.7	6.0	3.0
2036-40	7.0	3.5	7.5	3.8	7.8	3.9
2041-45	7.8	3.9	8.2	4.1	8.6	4.3
2046-50	8.5	4.2	10.3	5.2	11.0	5.5
2051-55	12.2	6.1	12.7	6.3	13.1	6.6
2056-60	12.9	6.4	13.6	6.8	14.0	7.0
2061-65	11.1	5.6	13.0	6.5	13.7	6.9
2066-70	14.4	7.2	15.1	7.6	15.5	7.8
2071-75	15.2	7.6	15.8	7.9	16.3	8.1
2076-80	12.9	6.5	15.0	7.5	15.7	7.8
2081-85	16.3	8.2	16.9	8.4	17.4	8.7
Post-2085	123.1	6.6	126.1	63.0	127.1	63.5
TOTAL	251.3	125.6	268.2	134.1	276.3	138.1

(*) Reference Case: 760 fatal cancers/million-person-WLM
(**) Alternative Case: 380 fatal cancers/million-person-WLM

EXHIBIT 8-4(C):

RESULTS OF BENEFITS SENSITIVITY ANALYSIS AT FUTURE MILLS: 1520 FATAL CANCERS/MILLION-PERSON-WLM

(avoided fatal cancers)

Period	Single Cell - Cover in 5 Years		Phased Disposal		Continuous Disposal	
	Reference Case(*)	Alternative Case(**)	Reference Case	Alternative Case	Reference Case	Alternative Case
1986-90	0.0	0.0	0.0	0.0	0.0	0.0
1991-95	0.0	0.0	0.0	0.0	0.0	0.0
1996-00	0.0	0.0	0.0	0.0	0.0	0.0
2001-05	0.0	0.0	0.1	0.2	0.2	0.4
2006-10	0.0	0.0	0.1	0.2	0.3	0.6
2011-15	0.0	0.0	0.1	0.2	0.3	0.6
2016-20	0.0	0.0	1.5	3.0	2.0	4.0
2021-25	3.0	6.0	3.2	6.4	3.5	7.0
2026-30	3.3	6.6	3.6	7.2	3.9	7.8
2031-35	3.7	7.4	5.4	10.8	6.0	12.0
2036-40	7.0	14.0	7.5	15.0	7.8	15.6
2041-45	7.8	15.6	8.2	16.4	8.6	17.2
2046-50	8.5	17.0	10.3	20.6	11.0	22.0
2051-55	12.2	24.4	12.7	25.4	13.1	26.2
2056-60	12.9	25.8	13.6	27.2	14.0	28.0
2061-65	11.1	22.2	13.0	26.0	13.7	27.4
2066-70	14.4	28.8	15.1	30.2	15.5	31.0
2071-75	15.2	30.4	15.8	31.6	16.3	32.6
2076-80	12.9	25.8	15.0	30.0	15.7	31.4
2081-85	16.3	32.6	16.9	33.8	17.4	34.8
Post-2085	123.1	246.2	126.1	252.2	127.1	254.2
TOTAL	251.3	502.6	268.2	536.4	276.3	552.6

(*) Reference Case: 760 fatal cancers/million-person-WLM
(**) Alternative Case: 1520 fatal cancers/million-person-WLM

EXHIBIT 8-5(A):

RESULTS OF BENEFITS SENSITIVITY ANALYSIS AT EXISTING MILLS: HIGHER PRODUCTION

(avoided fatal cancers)

	Cover by 1990		Cover by 1995		Cover by 2000		Cover by 2005		Interim Only	
Period	Reference Case(*)	Alternative Case(**)	Reference Case	Alternative Case	Reference Case	Alternative Case	Reference Case	Alternative Case	Reference Case	Alternative Case
1986-90	-1.6	-1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.9	1.9
1991-95	19.4	18.7	-1.6	-1.7	0.0	0.0	0.0	0.0	6.2	5.7
1996-00	19.9	19.1	20.0	19.4	-1.1	-1.5	0.0	0.0	4.3	4.3
2001-05	21.4	20.9	21.4	21.1	21.4	21.0	0.0	0.0	8.2	7.6
2006-10	22.3	22.2	22.3	22.4	22.4	22.4	22.4	22.4	10.1	10.1
2011-15	22.3	22.2	22.3	22.4	22.4	22.4	22.4	22.4	10.1	10.1
2016-20	22.3	22.2	22.3	22.4	22.4	22.4	22.4	22.4	10.1	10.1
2021-25	22.3	22.2	22.3	22.4	22.4	22.4	22.4	22.4	10.1	10.1
2026-30	18.4	18.4	18.5	18.5	18.5	18.5	18.6	18.6	7.8	7.8
2031-35	4.5	5.5	4.5	5.7	4.5	5.6	4.6	5.7	2.8	3.4
2036-40	4.2	5.3	4.3	5.5	4.3	5.3	4.4	5.4	2.6	3.2
2041-45	3.1	4.2	3.1	4.3	3.2	4.2	3.3	4.3	1.9	2.5
2046-50	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
2051-55	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
2056-60	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
2061-65	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
2066-70	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
2071-75	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
2076-80	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
2081-85	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
TOTAL	177.4	177.9	158.5	159.7	140.0	142.0	121.0	124.0	76.0	77.0

(*) Reference Case: Low Production
(**) Alternative Case: Higher Production

Note: Detail may not add to totals due to independent rounding.

EXHIBIT 8-5(B):

RESULTS OF BENEFITS SENSITIVITY ANALYSIS AT EXISTING MILLS: 380 FATAL CANCERS/MILLION-PERSON-WLM

(avoided fatal cancers)

	Cover by 1990		Cover by 1995		Cover by 2000		Cover by 2005		Interim Only	
Period	Reference Case(*)	Alternative Case(**)	Reference Case	Alternative Case	Reference Case	Alternative Case	Reference Case	Alternative Case	Reference Case	Alternative Case
1986-90	-1.6	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.9
1991-95	19.4	9.7	-1.6	-0.8	0.0	0.0	0.0	0.0	6.2	3.1
1996-00	19.9	10.0	20.0	10.0	-1.1	-0.5	0.0	0.0	4.3	2.2
2001-05	21.4	10.7	21.4	10.7	21.4	10.7	0.0	0.0	8.2	4.1
2006-10	22.3	11.1	22.3	11.2	22.3	11.2	22.4	11.2	10.1	5.1
2011-15	22.3	11.1	22.3	11.2	22.3	11.2	22.4	11.2	10.1	5.1
2016-20	22.3	11.1	22.3	11.2	22.3	11.2	22.4	11.2	10.1	5.1
2021-25	22.3	11.1	22.3	11.2	22.3	11.2	22.4	11.2	10.1	5.1
2026-30	18.4	9.2	18.5	9.2	18.5	9.2	18.6	9.3	7.8	3.9
2031-35	4.5	2.2	4.5	2.2	4.5	2.3	4.6	2.3	2.8	1.4
2036-40	4.2	2.1	4.3	2.1	4.3	2.2	4.4	2.2	2.6	1.3
2041-45	3.1	1.6	3.1	1.6	3.2	1.6	3.3	1.6	1.9	0.9
2046-50	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
2051-55	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
2056-60	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
2061-65	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
2066-70	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
2071-75	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
2076-80	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
2081-85	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
TOTAL	177	89	158	79	141	70	121	60	76	38

(*) Reference Case: 760 fatal cancers/million-person-WLM
(**) Alternative Case: 380 fatal cancers/million-person-WLM

Note: Detail may not add to total due to independent rounding.

EXHIBIT 8-5(C):

RESULTS OF BENEFITS SENSITIVITY ANALYSIS AT EXISTING MILLS: 1520 FATAL CANCERS/MILLION-PERSON-WLM

(avoided fatal cancers)

Period	Cover by 1990		Cover by 1995		Cover by 2000		Cover by 2005		Interim Only	
	Reference Case(*)	Alternative Case(**)	Reference Case	Alternative Case	Reference Case	Alternative Case	Reference Case	Alternative Case	Reference Case	Alternative Case
1986-90	-1.6	-3.2	0.0	0.0	0.0	0.0	0.0	0.0	1.9	3.8
1991-95	19.4	38.9	-1.6	-3.1	0.0	0.0	0.0	0.0	6.2	12.4
1996-00	19.9	39.9	20.0	39.9	-1.1	-2.1	0.0	0.0	4.3	8.7
2001-05	21.4	42.7	21.4	42.8	21.4	42.8	0.0	0.0	8.2	16.5
2006-10	22.3	44.6	22.3	44.6	22.3	44.7	22.4	44.8	10.1	20.3
2011-15	22.3	44.6	22.3	44.6	22.3	44.7	22.4	44.8	10.1	20.3
2016-20	22.3	44.6	22.3	44.6	22.3	44.7	22.4	44.8	10.1	20.3
2021-25	22.3	44.6	22.3	44.6	22.3	44.7	22.4	44.8	10.1	20.3
2026-30	18.4	36.9	18.5	36.9	18.5	37.0	18.6	37.2	7.8	15.7
2031-35	4.5	8.9	4.5	9.0	4.5	9.0	4.6	9.2	2.8	5.5
2036-40	4.2	8.5	4.3	8.6	4.3	8.6	4.4	8.8	2.6	5.3
2041-45	3.1	6.2	3.1	6.3	3.2	6.3	3.3	6.5	1.9	3.8
2046-50	-0.1	-0.3	-0.1	-0.2	-0.1	-0.2	0.0	0.0	0.0	0.0
2051-55	-0.1	-0.3	-0.1	-0.2	-0.1	-0.2	0.0	0.0	0.0	0.0
2056-60	-0.1	-0.3	-0.1	-0.2	-0.1	-0.2	0.0	0.0	0.0	0.0
2061-65	-0.1	-0.3	-0.1	-0.2	-0.1	-0.2	0.0	0.0	0.0	0.0
2066-70	-0.1	-0.3	-0.1	-0.2	-0.1	-0.2	0.0	0.0	0.0	0.0
2071-75	-0.1	-0.3	-0.1	-0.2	-0.1	-0.2	0.0	0.0	0.0	0.0
2076-80	-0.1	-0.3	-0.1	-0.2	-0.1	-0.2	0.0	0.0	0.0	0.0
2081-85	-0.1	-0.3	-0.1	-0.2	-0.1	-0.2	0.0	0.0	0.0	0.0
TOTAL	177	355	158	317	141	279	121	241	76	153

(*) Reference Case: 760 fatal cancers/million-person-WLM
(**) Alternative Case: 1520 fatal cancers/million-person-WLM

Note: Detail may not add to totals due to independent rounding.

CHAPTER 9:

ECONOMIC IMPACTS

Any regulatory alternative will increase the cost of domestically produced U_3O_8. The amount of this impact will depend on the regulation selected. If it were determined that the 1984 present value of the additional cost for future and existing disposal was $630 million at a 10 percent discount rate, the impact on consumers and investors could be evaluated. This figure is about 10 percent higher than any of the cost estimates presented in Chapter 6. In this chapter we will evaluate the effect of such a regulatory cost. The impact of any of the alternative regulations from Chapter 6 will be smaller and can be scaled from the impacts calculated here. If the U.S. Uranium Industry created a annuity payment to cover the added cost of this regulation, the payments required per year would be $151 million in each year for 5 years, or $93 million for each year for 10 years. In this chapter the impact of these cost increases on investors in this industry or purchasers of electricity are presented.

9.1 INCREASED PRODUCTION COST

The added production cost resulting from the regulation may, or may not, be passed on to the consumers of U_3O_8 (electric utilities). If the added cost is translated into higher prices for U_3O_8, then the consumers of electric power will ultimately be charged higher rates, particularly those customers of utilities with a high reliance on nuclear generating capacity. If the U.S. uranium milling industry is unable to pass on the disposal costs internalized by this regulation as a result of downward pressure on U_3O_8 prices from foreign competition or other factors then the added costs will ultimately be paid by the investors in firms in the uranium mining and milling industry.

No attempt is made here to specify the supply and demand curves for U_3O_8. Instead two extreme situations are considered. The first case is based on the assumption that the uranium mills are unable to pass any of the costs of the regulation on in higher U_3O_8 prices, and the second case is based on the assumption that the uranium mills are able to recover all increased cost of the disposal through increased U_3O_8 prices. This presentation is designed to present two extreme possibilities for which the range of impacts will bracket the likely impacts. In fact, some of these costs will surely find their way into the rate base of utilities with nuclear generating capacity. In addition, since some owners of these existing impoundments are no longer operating nor do they ever intend to operate in this industry in the future, their cost for disposal must be borne by the investors in these firms.

It is assumed in the first case that no portion of the cost of the regulation can be passed on to the buyer of U_3O_8. Selected average financial statistics for 1980-84 from the domestic uranium industry (see Chapter 2 for details) are presented in Exhibit 9-1. These data are compared to the present value cost impacts of the regulation and to the required annuity payment to ammortize these costs over five or ten years. The 1980-84 period is one in which the industry was contracting and experiencing substantial losses due to excess production capacity. The present value cost of the regulation would be about four times the industry losses over this period. It is equal to about 20 percent of the book value of industry assets and about 40 percent of industry liabilities. The ten year annuity payment would require about a 6 percent annual increase in liabilities for 10 years to internalize the environmental control costs.

In the second case it is assumed that the uranium industry is able to recover the entire increase in tailings disposal cost by charging higher U_3O_8 prices. This increased input cost to electric utilities will ultimately be added to the rate base and paid by electric power consumers.

The revenue earned by the utility industry for generating 2.4 trillion kilowatthours of electricity in 1984 was 142.31 billion dollars. The 1984 present value of the regulation (630 million) is less than 1 percent (.44%) of the U.S. total electric power revenue for the same year. Exhibit 9-2 is a presentation of the relationship of the regulatory cost to power generation.

The increased cost of total generation reflects a change in the average cost per unit for the nation. The regional impacts will vary from this mean, based in part, on the dependence on nuclear power by region as shown in Exhibit 9-3. The ERCOT Region, for example, with no nuclear generating capacity would probably feel no effect from the cost of the regulation in higher electricity prices, and other regions, like MAIN and SERC, would suffer the greatest affects. As for a specific customer or community, the

EXHIBIT 9-1: COMPARISONS OF THE PRESENT VALUE OF THE ESTIMATED COST IMPACTS WITH SELECTED FINANCIAL STATISTICS OF THE DOMESTIC URANIUM INDUSTRY

	Domestic Uranium[a/] Industry, 1980-1984 Average (million $)	Present Value Cost As a Percent of Each Industry Statistic	Annual Five Year Annuity Payment as a Percent of Each Industry Statistic	Annual Ten Year Annuity Payment as a Percent of Each Industry Statistic
Operating Revenues	850	74	18	11
Net Income (Loss)	(31)	2032	487	300
Total Sources of Funds	532	118	28	17
Capital Expenditures	195	323	77	48
Total Uses of Funds	469	134	32	20
Current Assets (less inventory)	275	229	55	34
Total Assets	2862	22	5	3
Total Liabilities	1668	38	9	6

[a]DOE 85a.

Note: Present value cost is assumed to be $630 million 1984 dollars. Five year annuity payment is $151 million per year and ten year annuity payment is $93 million per year.

EXHIBIT 9-2:
IMPACTS ON ELECTRIC POWER COST

	Total Electric Power Industry	Nuclear Electric Power Only
1984[a] Generation Million Kilowatt-hours	2,416,000	327,000
Dollars of Utility Revenue Per Million Kilowatt-hours	58,903	58,903
Dollars of Present Value of Added Cost of Disposal Per Million Kilowatt-hours	261	1926
Dollars of Annual Cost of 5 Year Annuity Per Million Kilowatt-hours	63	462
Dollars of Annual Cost of 10 Year Annuity Per Million Kilowatt-hours	38	284

[a]DOE 85b.

Note: Present value cost is assumed to be $630 million 1984 dollars. Five year annuity payment is $151 million per year and ten year annuity payment is $93 million per year.

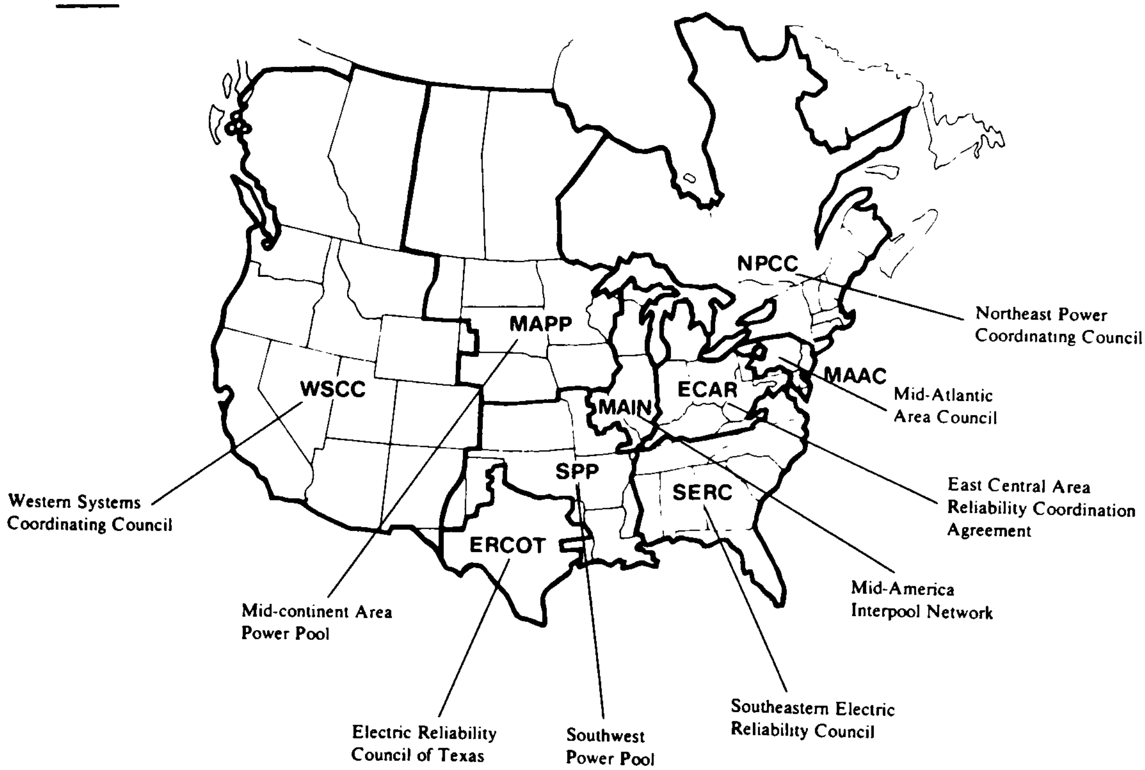
EXHIBIT 9-3:

ELECTRICAL GENERATION BY NERC REGION 1984[a]

Region	Total Generation (GWH)	Nuclear Generation (GWH)	Percent of Total From Nuclear
ECAR	421,281	23,175	5.5
ERCOT	174,958	—	—
MAAC	166,806	34,040	20.4
MAIN	170,940	46,323	27.1
MAPP(U.S.)	107,346	17,127	16.0
NPCC(U.S.)	189,871	44,973	23.7
SERC	491,724	126,774	25.8
SPP	218,646	10,973	5.0
WSCC(U.S.)	464,018	24,248	5.2

[a]DOE 85b.

KEY:



level of impact is dependent upon the percent of generation from nuclear that their particular electrical utility utilizes. For example, Commonwealth Edison of Illinois and Duke Power of North Carolina have two of the highest percentage of power from nuclear sources, so their customers would be more severely impacted than customers in other utilities.

9.2 REGULATORY FLEXIBILITY ANALYSIS

The Regulatory Flexibility Act (RFA) requires regulators to determine whether proposed regulations would have a significant economic impact on a substantial number of small businesses or other small entities. If such impacts exist, they are required to consider specific alternative regulatory structures to minimize the small entity impacts without compromising the objective of the statute under which the rule is enacted. Alternatives specified for consideration by the RFA are tiering regulations, performance rather than design standards, and small firm exemptions.

Most firms that own uranium mills are divisions or subsidiaries of major U.S. and international corporations (See section 2.3 above). Many of these uranium mining and milling operations are parts of larger diversified mining firms that are engaged in many raw materials industries and uranium represents only a small portion of their operations. Others are owned by major oil companies or by electric utilities who engaged in vertical integration during the 1960's and 1970's. In 1977 there were 26 companies operating uranium mills and at the start of 1986 only two were operating. The future of this industry suggests that only a limited number of these existing facilities will ever operate again. It is also expected that the high level of financial risk and capital requirements will continue to attract only large diversified firms and electric utilities to this industry. Thus, no significant impact on small businesses is expected.

REFERENCES

DOE 85a Department of Energy, Domestic Uranium Mining and Milling Industry: 1984 Viability Assessment. DOE/EIS-0477, September 1985.

DOE 85b Department of Energy, Electric Power Annual 1984. DOE/EIA-0348(84), August 1985.

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