8 Canada's RW

Canada's LLW Volume Projections to year 2025.

Canadian nuclear industry	(m^3)	%
Refining	65,000	18
Fuel fabrication	14,800	4
Utilities	156,500	42
Isotopes and research	61,200	16
Licensed users	12,900	3
Industries using naturally radioactive feedstocks	57,100	15
Total	367,500	100

Irradiated fuel bays at Ontario Hydro's NGS.

Station	Type	Dimensions - m Width	Length	Depth	C	ISD	BFD	LM
Pickering A/B	PIFB	16.3	29.3	8.1	93/158	1972/83	1995	E
	AIFB	17	34	8.1	214	1978	1994	E
Bruce A/B	PIFB	10	41	6	21/36	1977/83	2002	SS+E
	IFB	18	46	9	352/330	1979/87	2002	SS+E
Darlington	PIFB	9.7	20.6	5	212	1987	1996	SS

C = capacity 1000's bundles, ISD = in-service date, BFD = bay fill date, LM = liner material (SS = Stainless steel, E = Epoxy)

Irradiated fuel bay purification system capacity.

Station	Type	F-l/s	E	Type	F	E
Pickering A/B	PIFB	12/64	IX	AIFB	65	F+IX
Bruce A/B	PIFB	76/76	IX	AIFB	38	IX
Darlington	PIFB	92	F+IX			

F = flow rate, E = equipment (F = filters, IX = ion exchange)

Used-fuel centre life-cycle cost and labour requirements.

	Cost - 1991 M$			Labour - person*years		
Estimate	low	nominal	high	low	nominal	high
Siting (23 a)	1850	2180	3050	6880	8100	11330
Construction (7 a)	1540	1810	2530	6240	7340	10280
Operation (41 a)	6850	8060	11280	33880	39850	55800
Decommissioning(16 a)	1060	1250	1750	5720	6730	9430
Closure (2 a)	30	30	40	120	150	200
Total	11320	13320	18650	52840	62170	87040

Scaled nominal cost (M$ 1991) and Duration (D in years) estimates for disposal vault capacities of 5, 7.5 and 10.1 Million used-fuel bundles at depth of 1000 m.

Million of bundles	5		7.5		10.1	
	D	Cost	D	Cost	D	Cost
Siting	23	2140	23	2160	23	2180
Construction	5	1520	6	1630	7	1810
Operation	20	4060	30	6040	41	8060
Decommissioning	13	940	15	1090	16	1250
Closure	2	30	2	30	2	30
Total	63	8680	76	10950	89	13320

Comparison of nominal cost (M$ 1991) and schedule durations (D in years) for a disposal centre with a vault at depths of 500 and 1000 m (Capacity = 10.1 million used-fuel bundles).

Depth =	500 m		1000 m	
	D	Cost	D	Cost
Siting	22	2110	23	2180
Construction	7	1780	7	1810
Operation	41	8060	41	8060
Decommissioning	14	1130	16	1250
Closure	2	30	2	30
Total	86	13110	89	13320

Percentage of contaminants present in different compartments at 1E+4 a.

Amount remaining in	I-129	C-14	Tc-99	U-238
Containers	96.06	28.0	91.0	99.99
Backfill + Buffer	3.85	1.9	5.79	2E-7
Geosphere	0.07	0.02	0	0
Released biosphere	0.02	0	0	0

Mean concentrations (MC) of contaminants in soil and water and their environmental increments (EI).

	129-I		14-C	
Medium	MC	EI	MC	EI
Soil Bq/kg	2	1E-5	9E-3	9E-3
Water Bq/L	3E-3	4E-8	5E-4	2E-5

Arithmetic mean of the maximum doses to four hypothetical organisms estimated in 1000 simulations for a 100 000-year simulation time (mGy/a).

Nuclide	Plant	Fish	Mammal	Bird
129-I	4E-3	3E-3	1E-2	5E-2
14-C	2E-4	2E-2	5E-4	5E-4
Total	4E-3	2E-2	1E-2	5E-2

Percentage of a nuclide released by a barrier over 100 000 years.

Nuclide	T - a	Fuel	Container	Vault	Rock
3-H	12.4	30	<<0.001	<<0.001	<<0.001
90-Sr	29.1	0.05	<<0.001	1	<<0.001
39-Ar	269	8	0.08	<<0.001	<<0.001
14-C	5730	6	60	0.8	0.007
239-Pu	2.41E+4	<<0.001	100	<<0.001	<<0.001
99-Tc	2.13E+5	6	100	<<0.001	0.1
129-I	1.57E+7	6	100	10	5
Br	stable	6	100	10	5
Sb	stable	<<0.001	100	0.003	5

Maximum Estimated Risk (MER) and Time of Occurrence (TO) from four human intrusion scenarios.

Scenario	MER/y	TO - y
Drilling	3E-10	40
Core Examination	9E-11	500
Construction	4E-13	3000
Resident	3E-10	150

Amounts of contaminants (in mol) present in different compartments at 1E+5 a.

Amount in	Br	C-14	I-129	Kr-81	Pu-239	U-238
Inventory*	11000	3000	56000	0.011	19E+5	67E+7
Containers	9900	0.015	52000	0.0072	1E+5	67E+7
Buffer	0	0	0	7E-5	5E-4	4.2
Backfill	590	16E-4	3100	5E-4	2E-4	8E-3
Vault	11000	16E-3	55000	8E-3	1E+5	67E+7
Released**	2E-2	81E-8	0.28	1E-8	0	0

* initial, ** to biosphere.

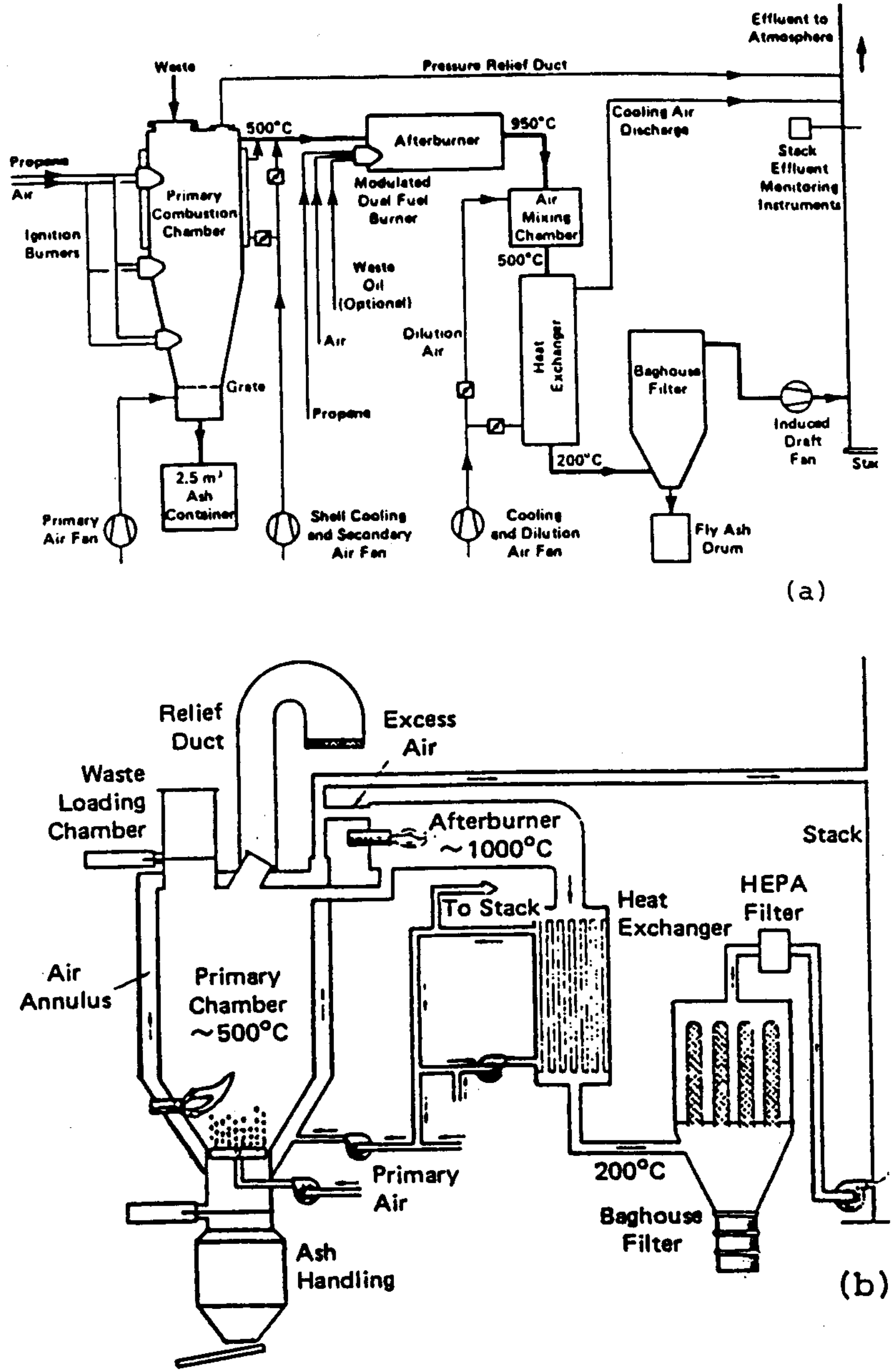


Figure 1: LLW Incinerators in Canada (a) Ontario Hydro (b) CRNL

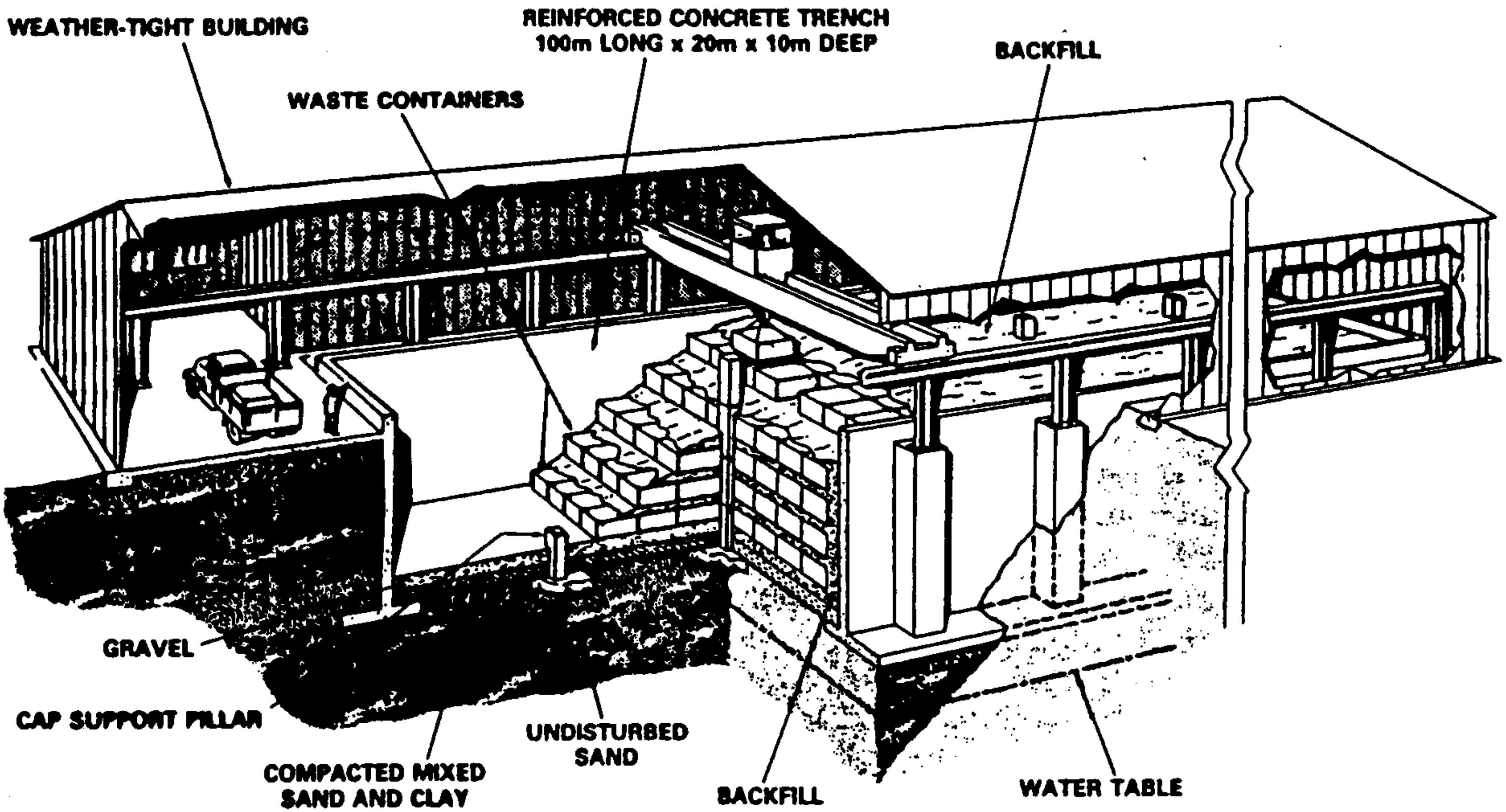
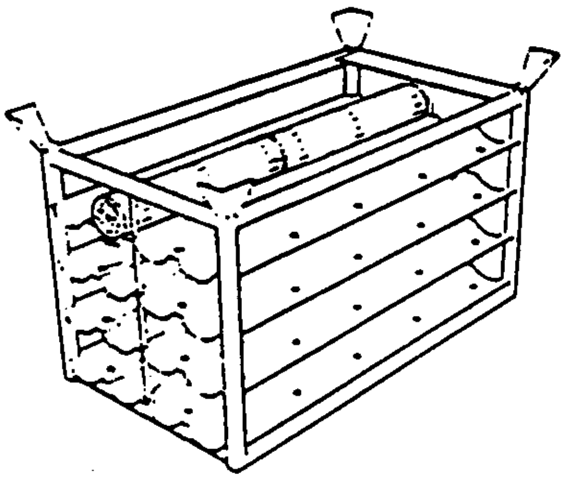


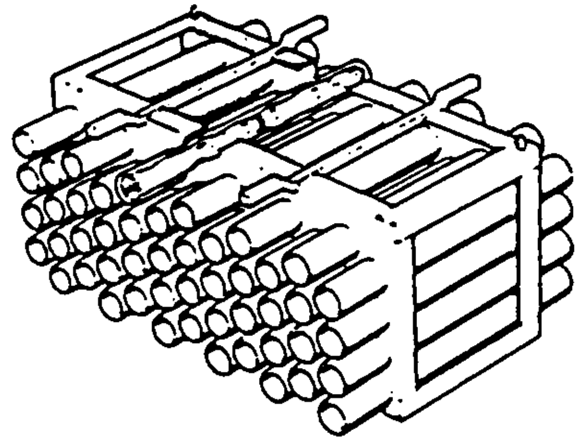
Figure 2: CRNL shallow land burial (SLB) facility.

LB

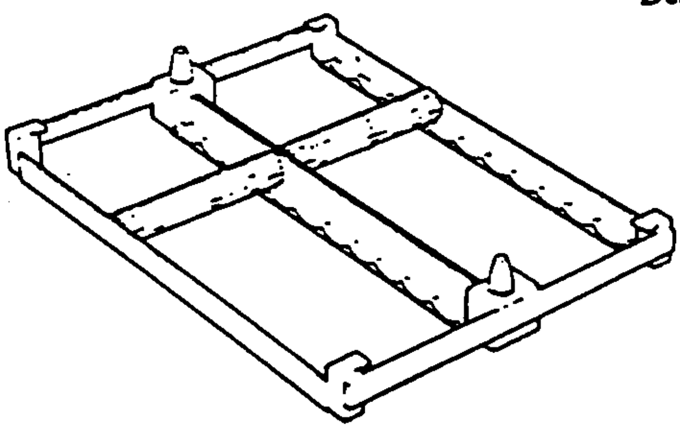
FS



Pickering GS
Fuel Storage Basket
(32 Bundle Capacity, Storage
Density = 1393 kg U/m^3)



Shipping and Storage Module
(96 Bundle Capacity, Storage
Density = 2189 kg U/m^3)



Bruce GS
Irradiated Fuel Storage Tray
(20 Bundle Capacity, Storage
Density = 1683 kg U/m^3)

Figure 2 Ontario Hydro Irradiated Fuel Storage Containers

FS∧I

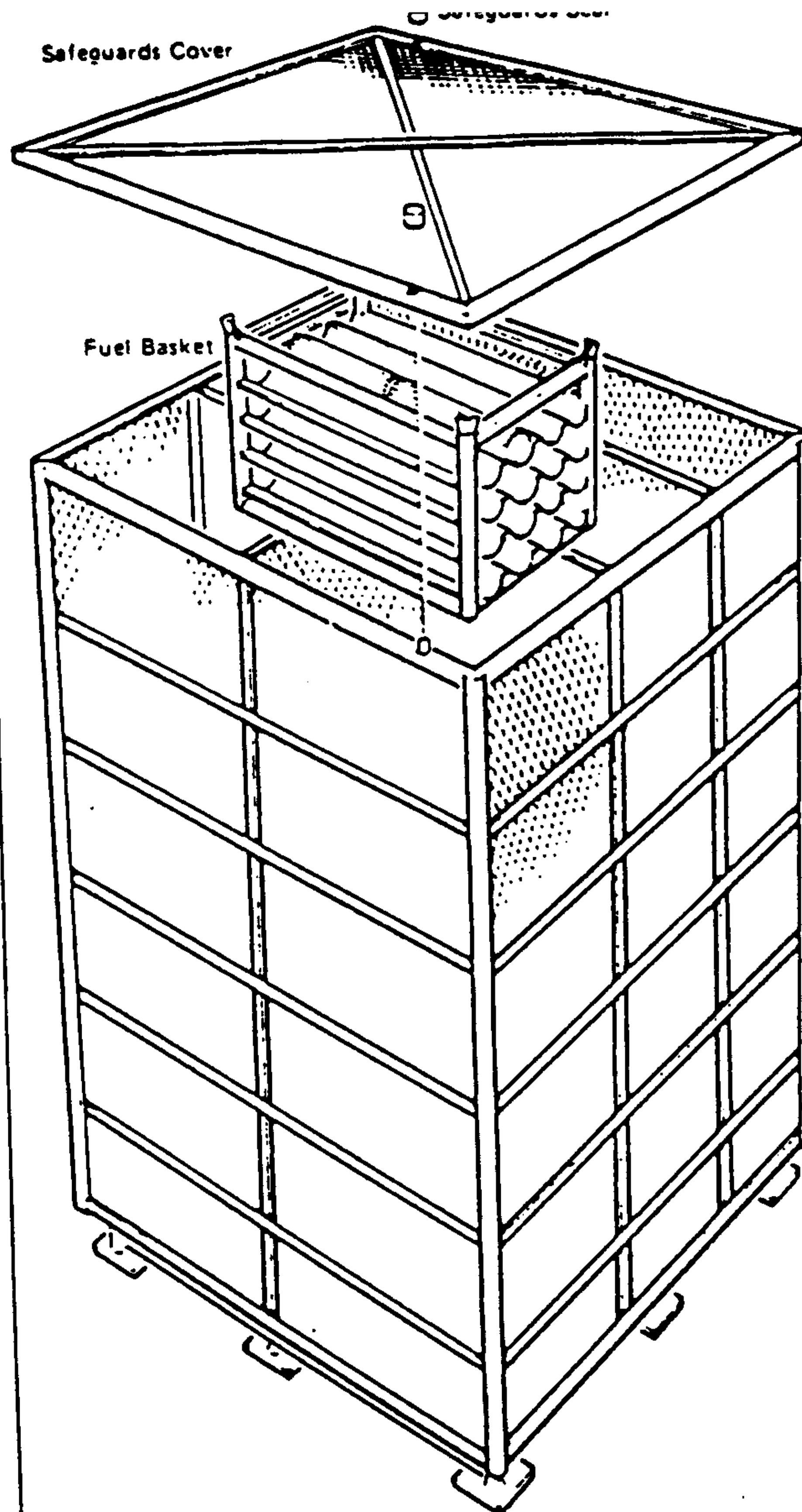


Figure 3 Pickering NGS-A Irradiated Fuel Stacking Frame

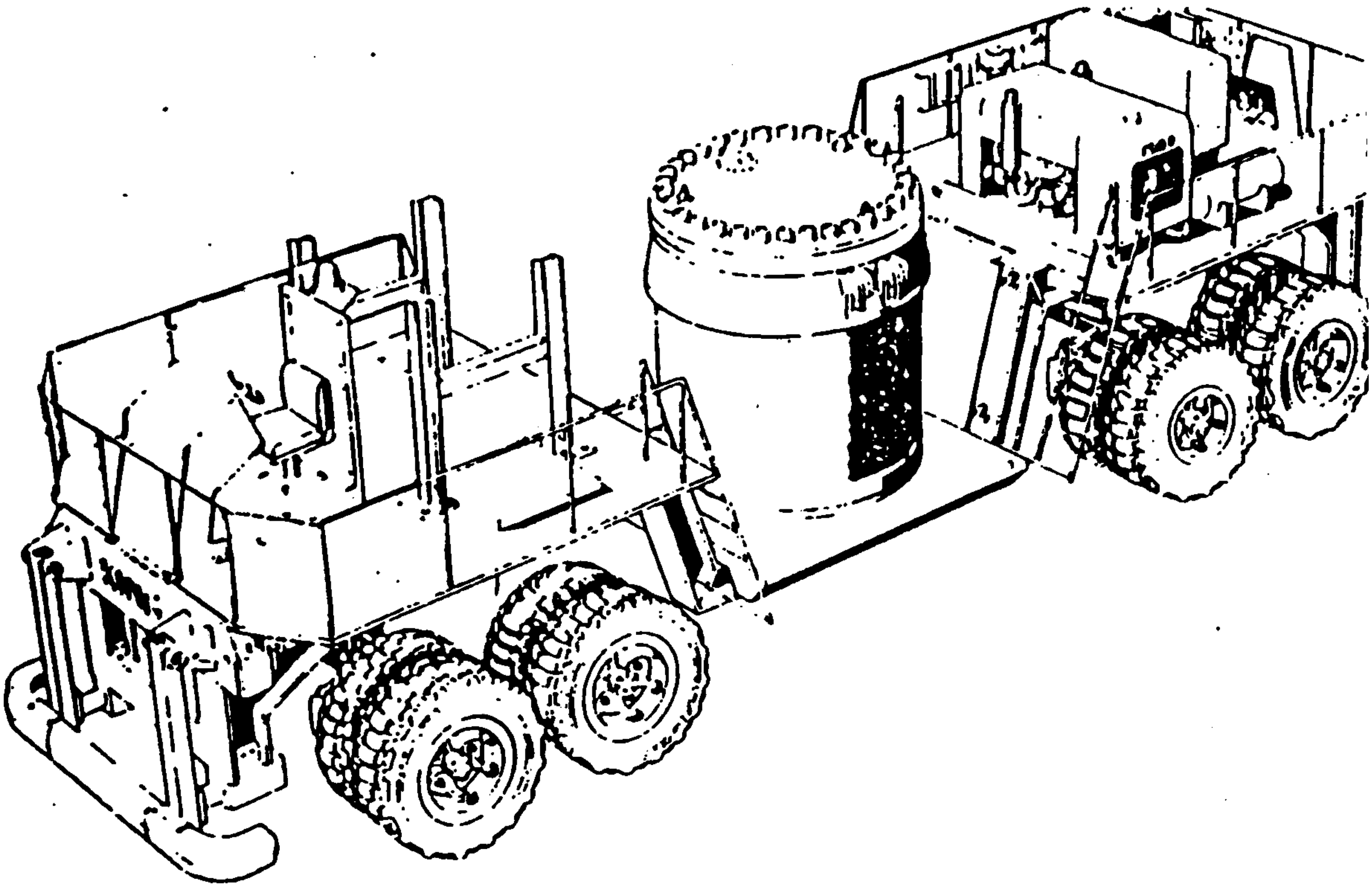
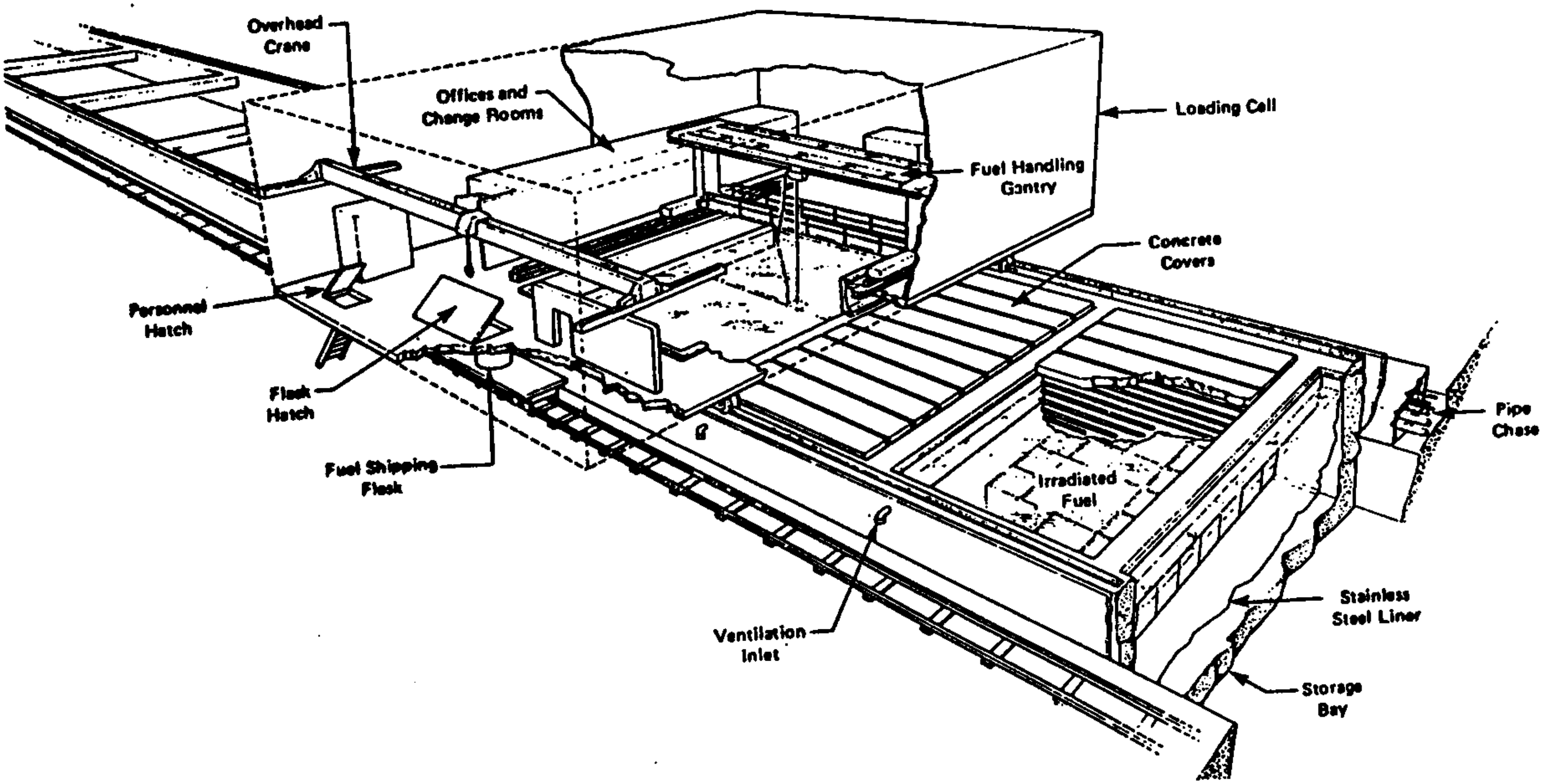


Figure 5. On-Site Flask Transfer Vehicle



FSH FIGURE 3: CENTRAL POOLS - CUTAWAY (From Ref. 5). AECL 6191

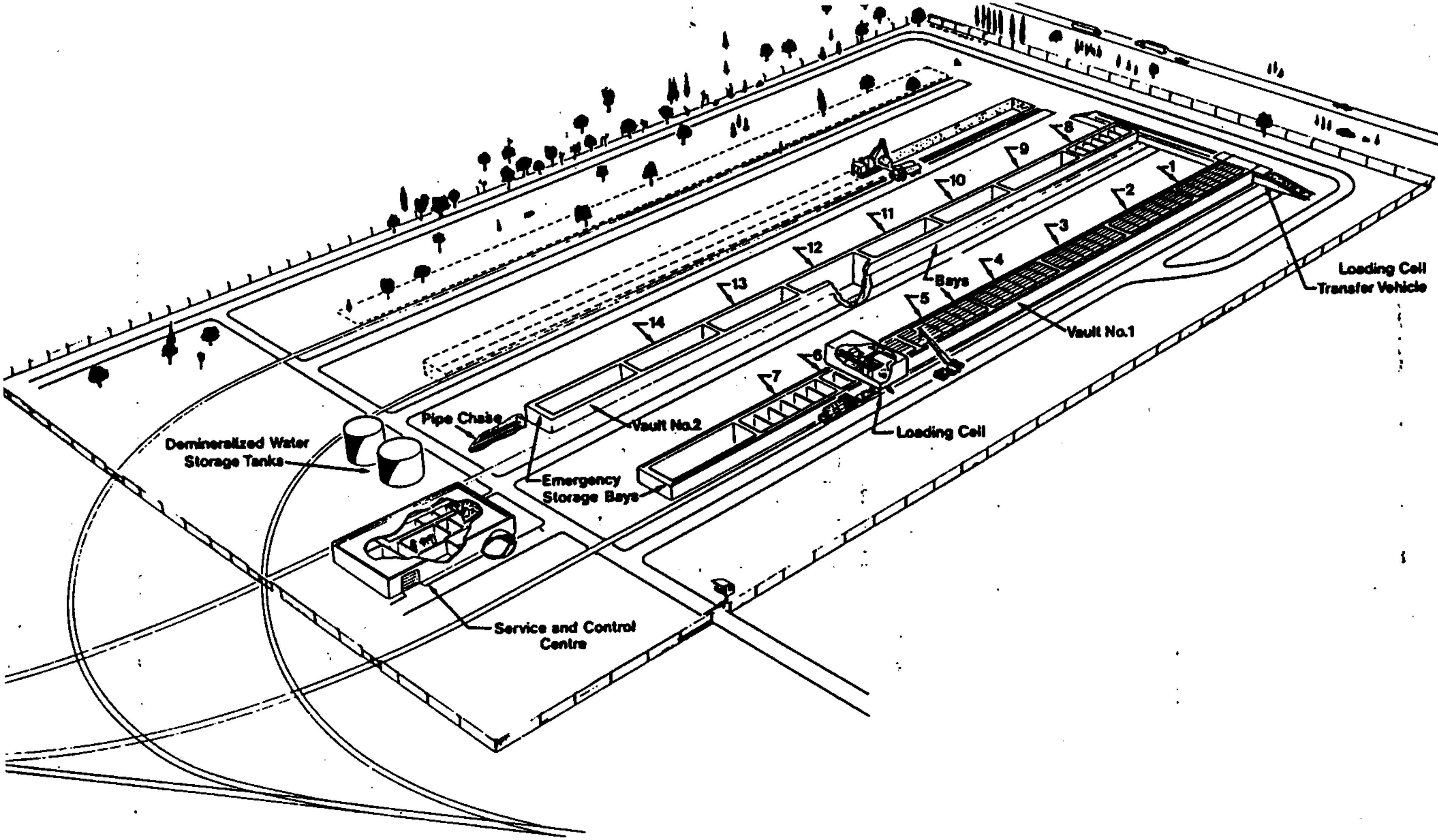


FIGURE 4: SPENT FUEL STORAGE FACILITY. AECL6191

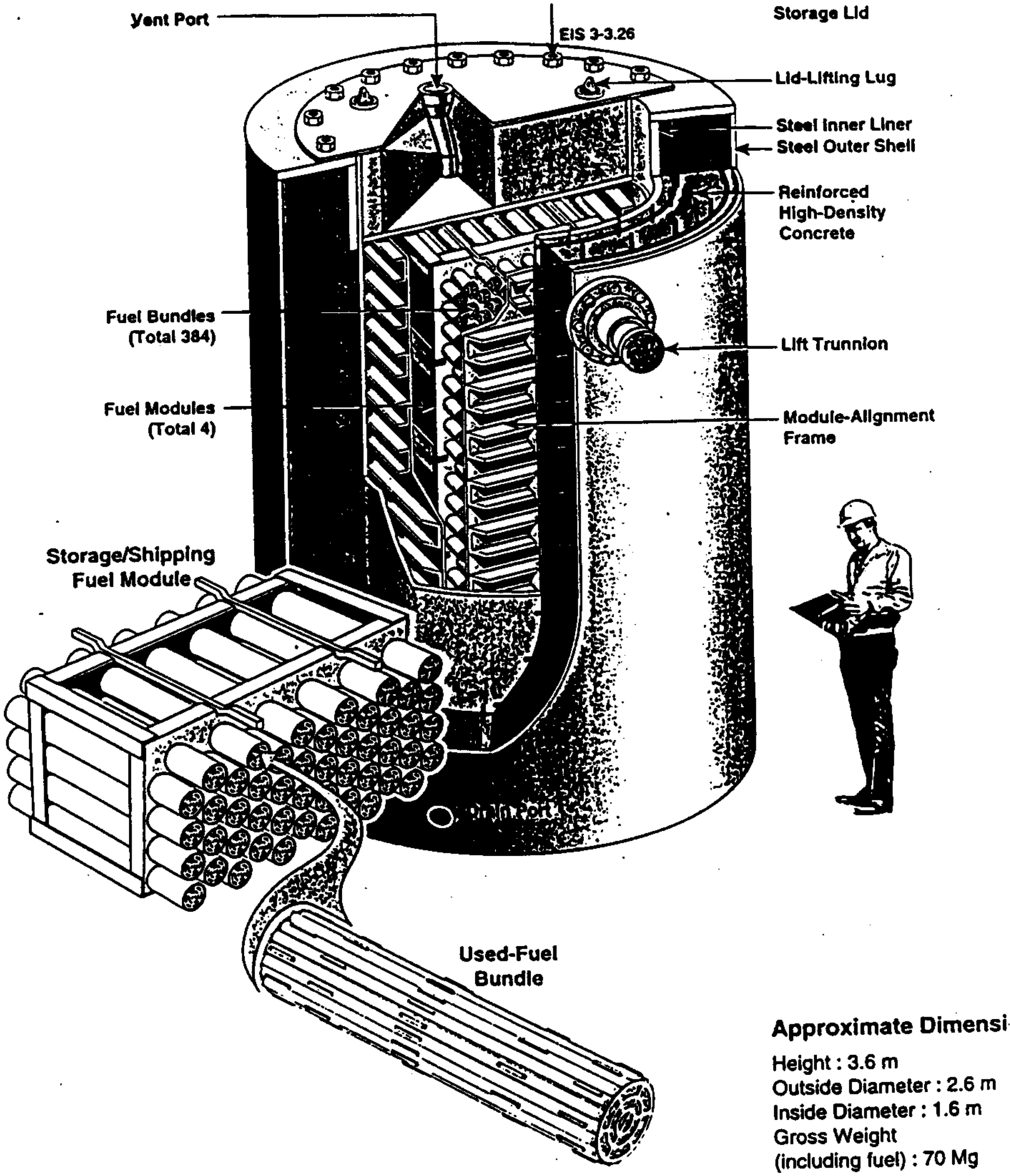


FIGURE 3-26: Ontario Hydro Dry Storage Container, Original Cylindrical Design

CSA

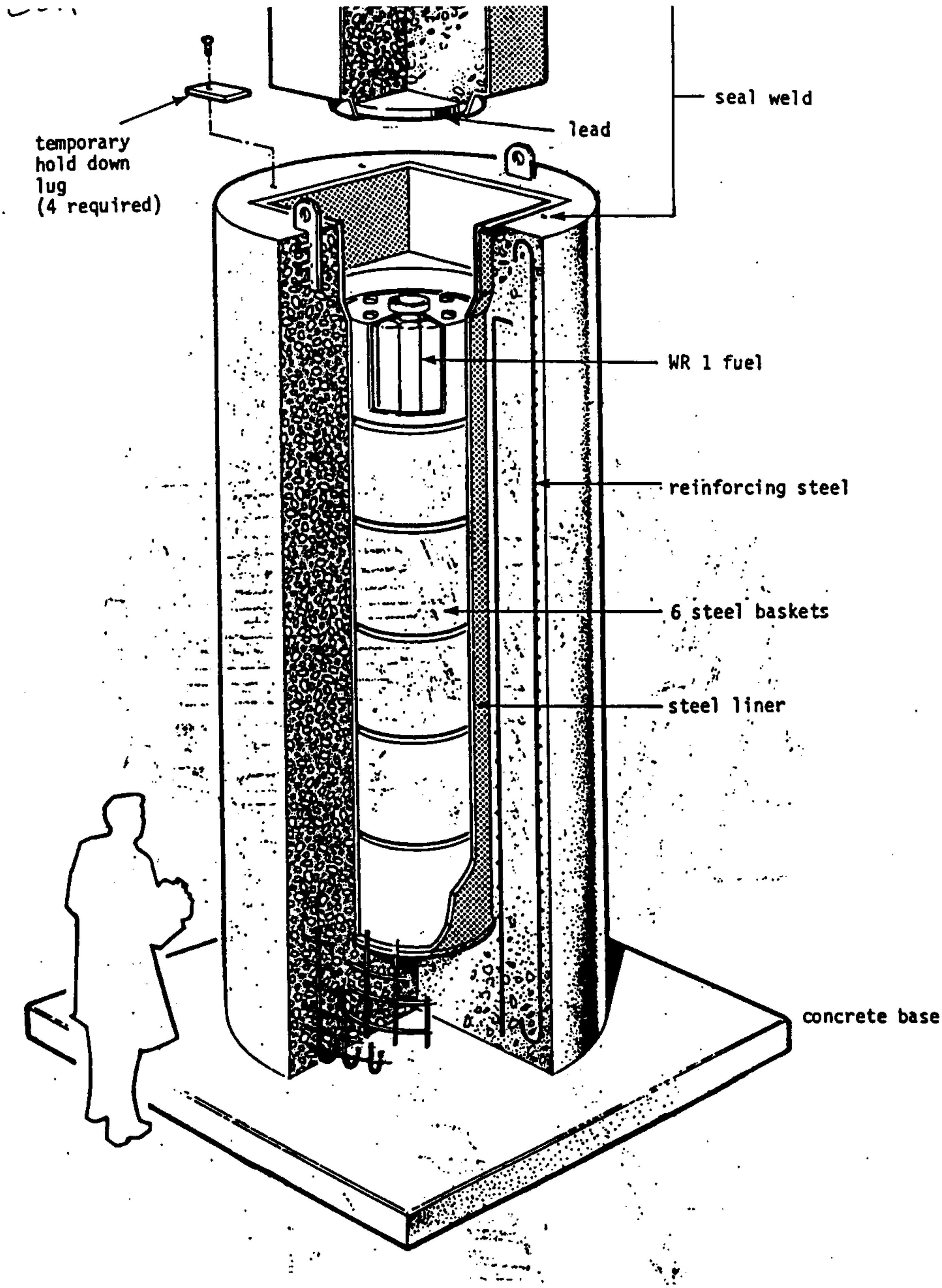


FIGURE 7: CYLINDRICAL CONCRETE CANISTER

AECL 6191

C3A

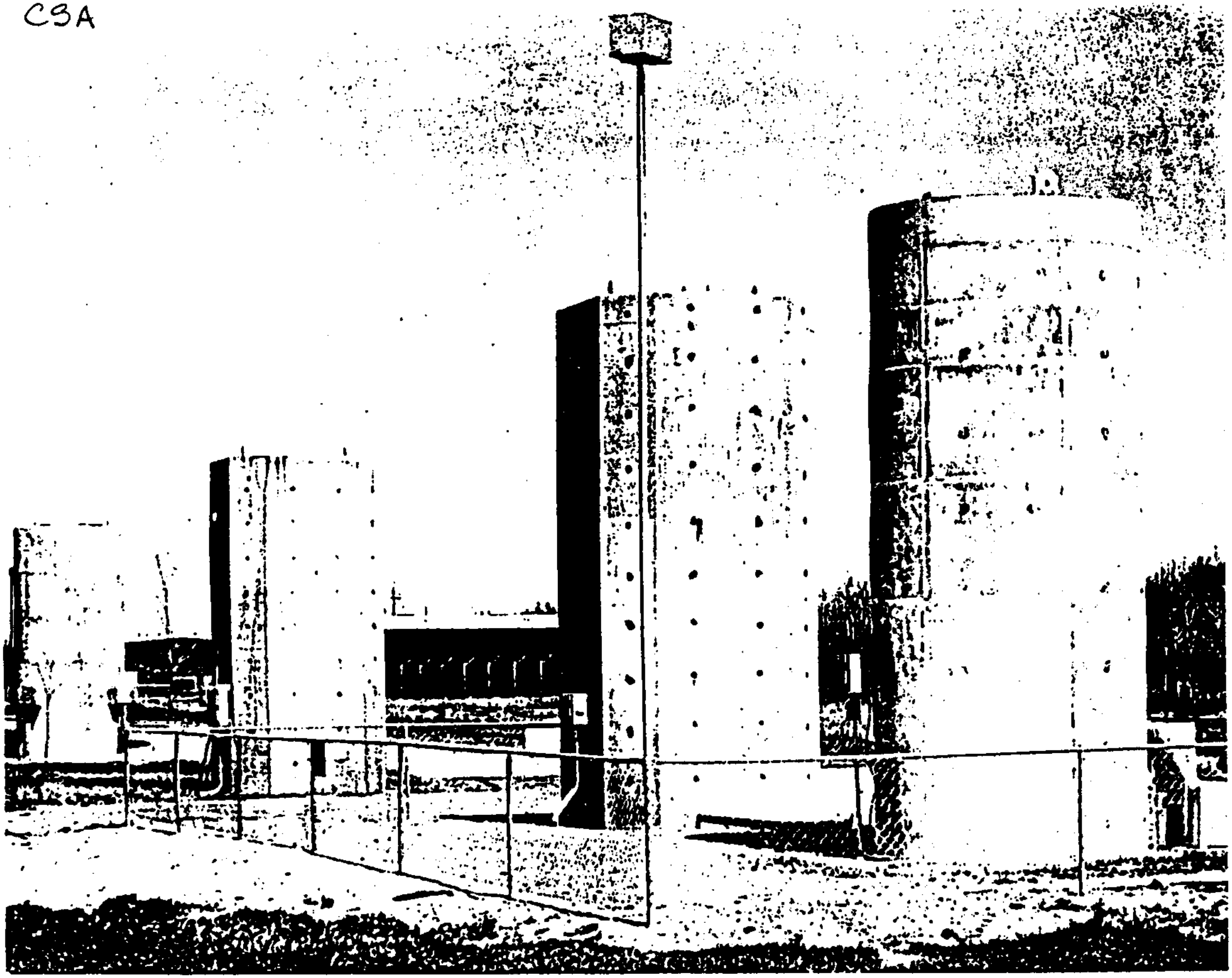


FIGURE 10: CANISTERS IN OPERATION. AECL 6191

CS

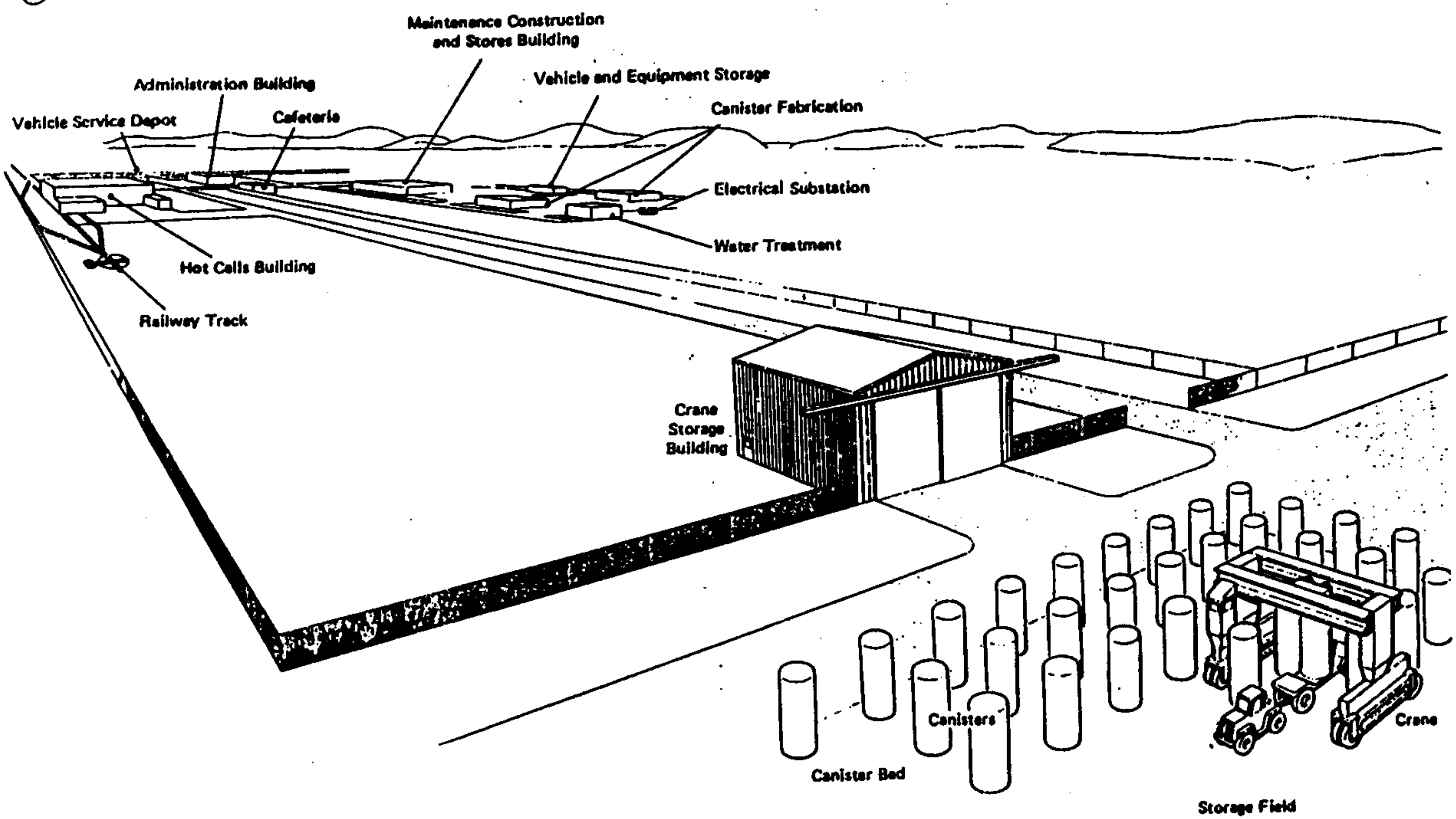
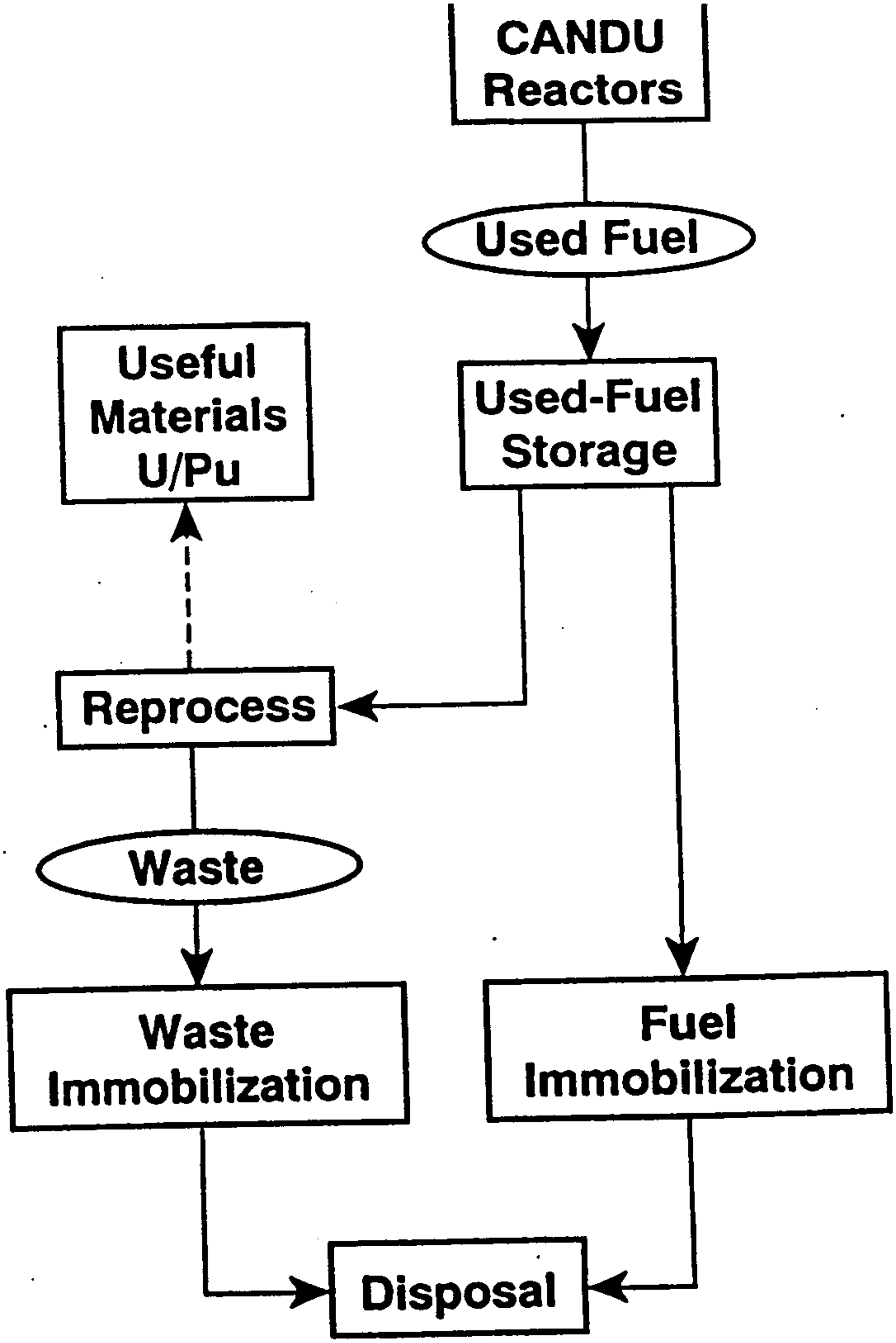


FIGURE 8: CANISTER STORAGE FACILITY. AECL 6121

F ...U



F 3-2.1

Options for the Storage and Disposal of

HDmO

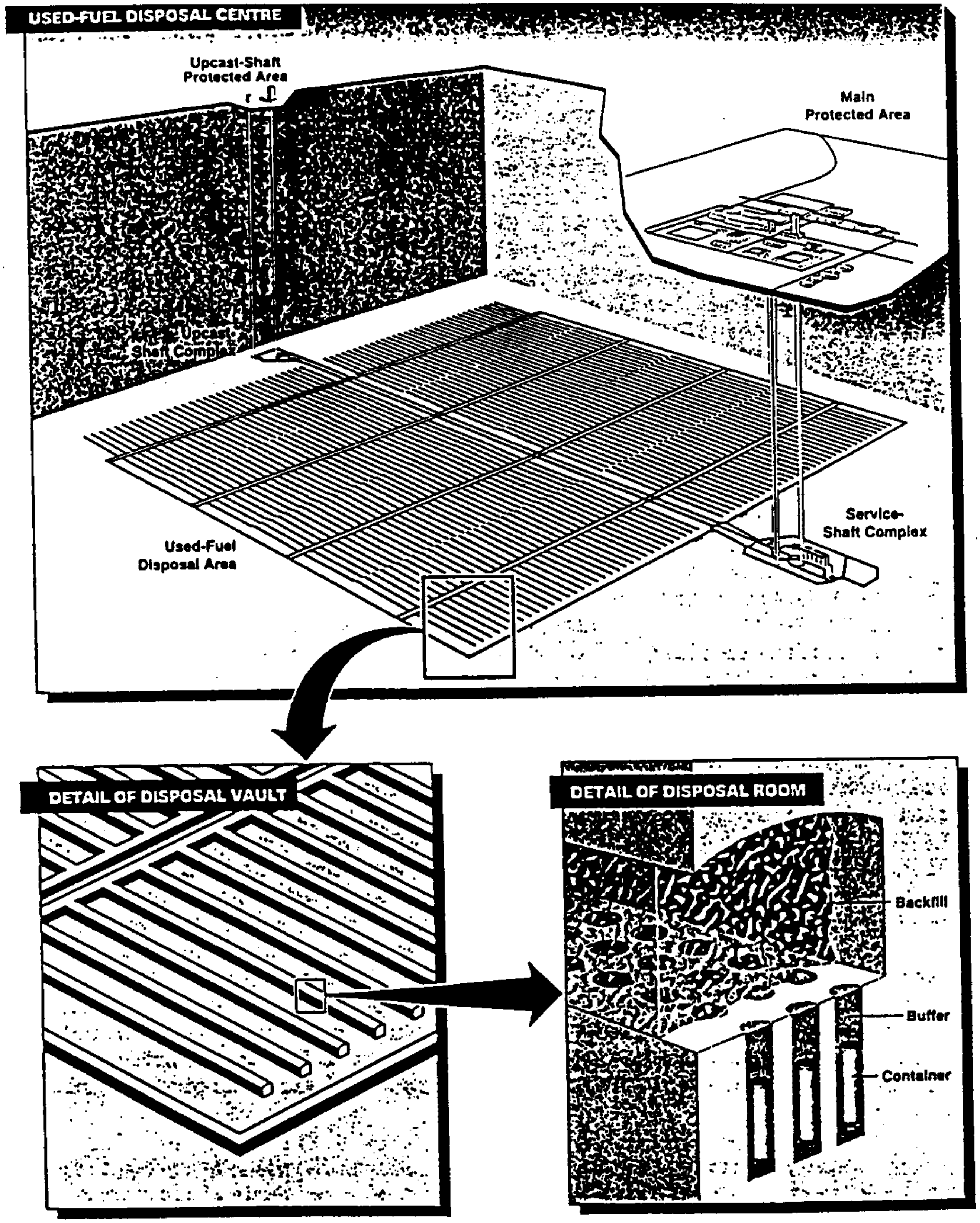


FIGURE ES-4: Used-Fuel Disposal Centre Perspective

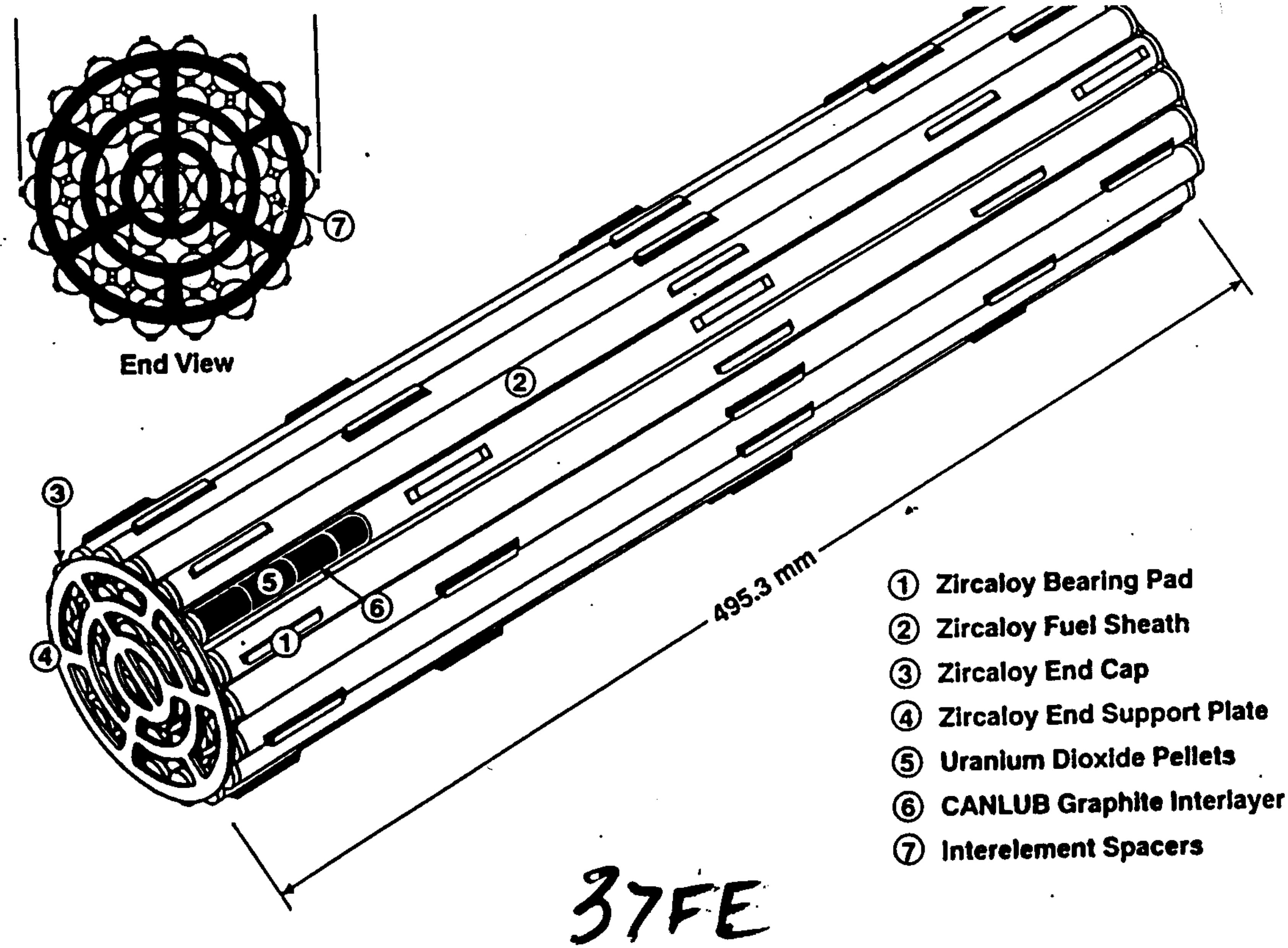


FIGURE ES-1: Typical CANDU Fuel Bundle for Bruce Nuclear Generating Station (after AECL CANDU et al. 1992)

of 685 GJ/kg U and cooled for 10 a after their discharge from a nuclear

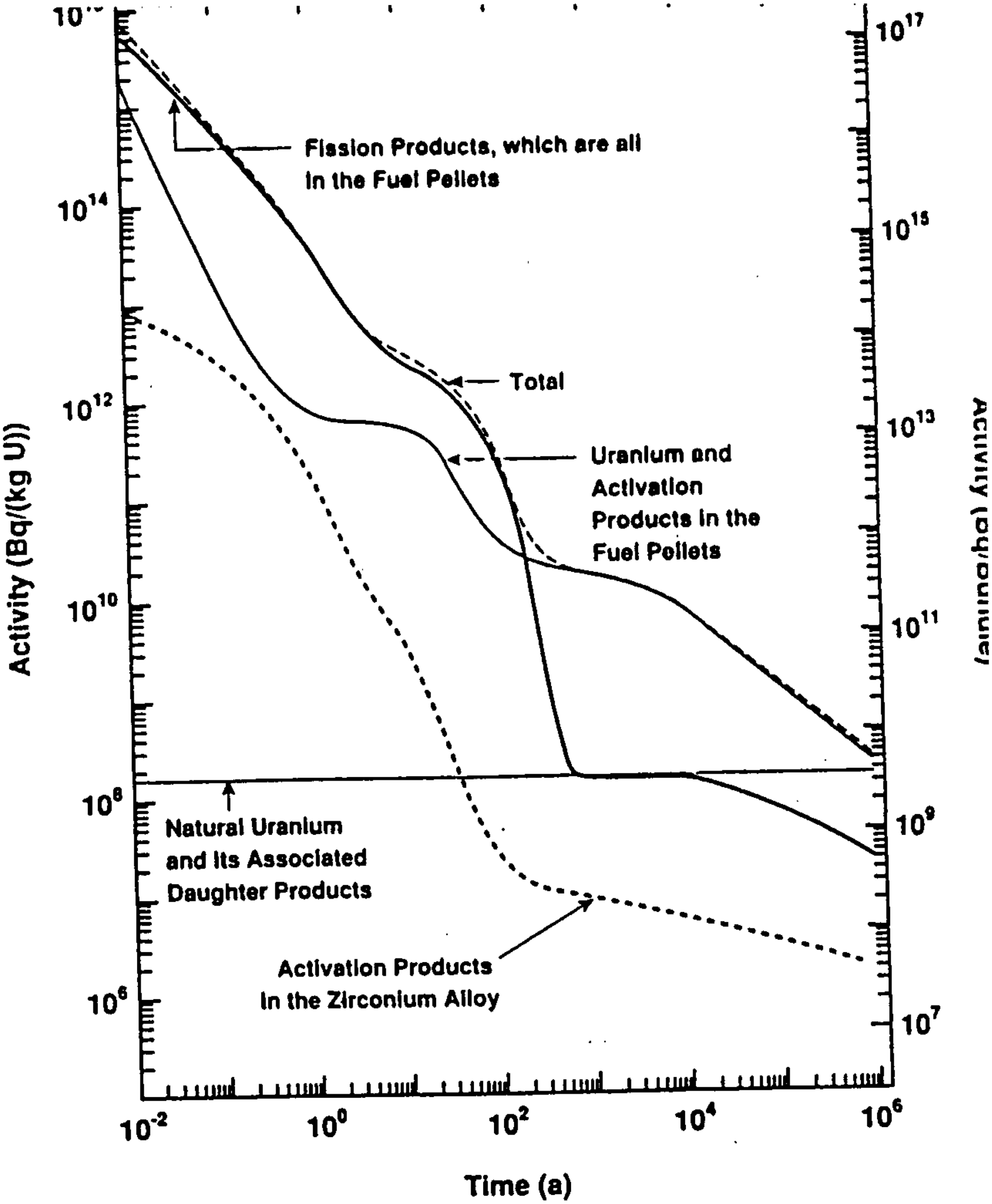


FIGURE 2-5: ACTIVITY OF THE USED FUEL SPECIFIED FOR THE CASE STUDIES (LOGARITHMIC SCALES)

FDAH

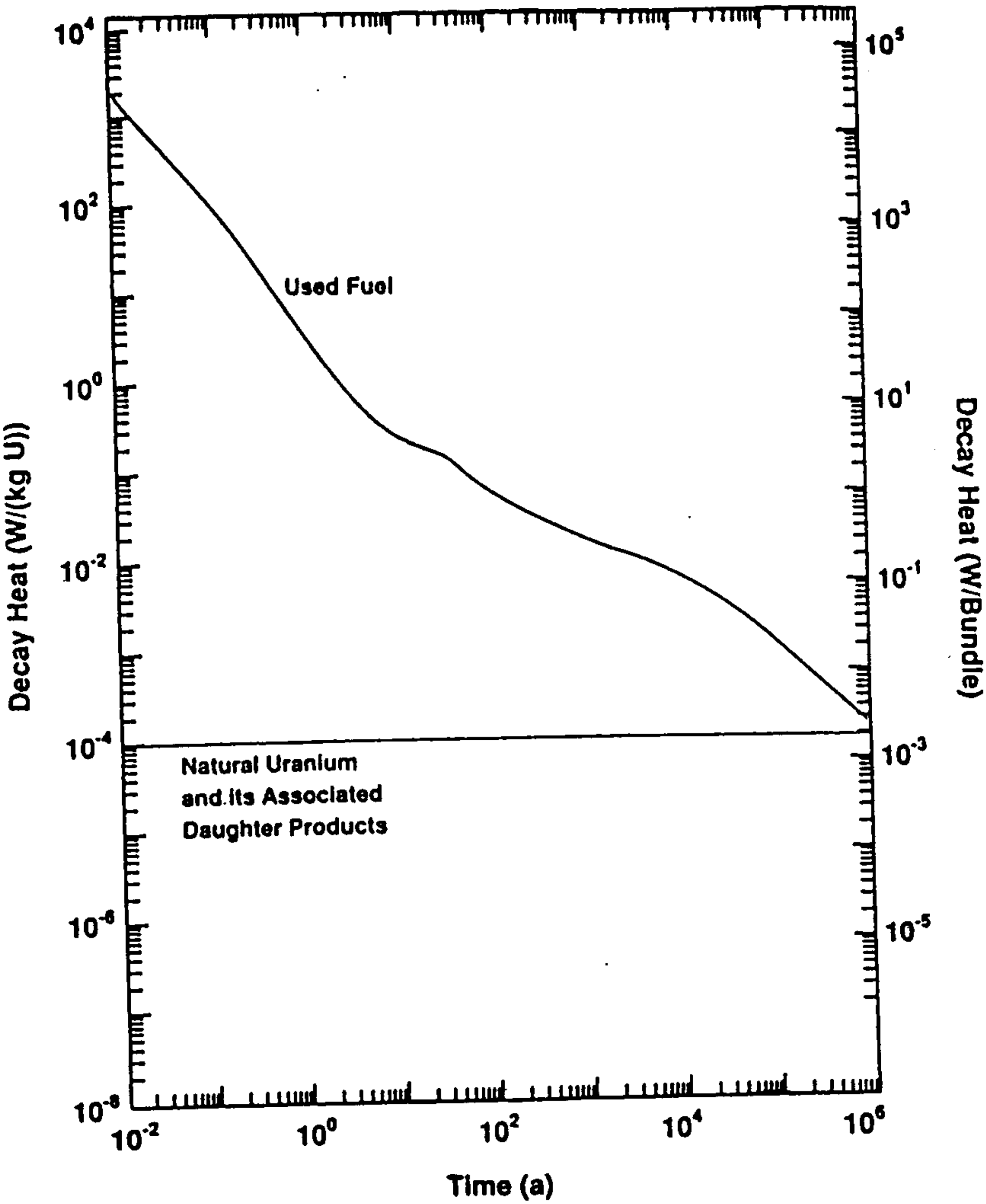
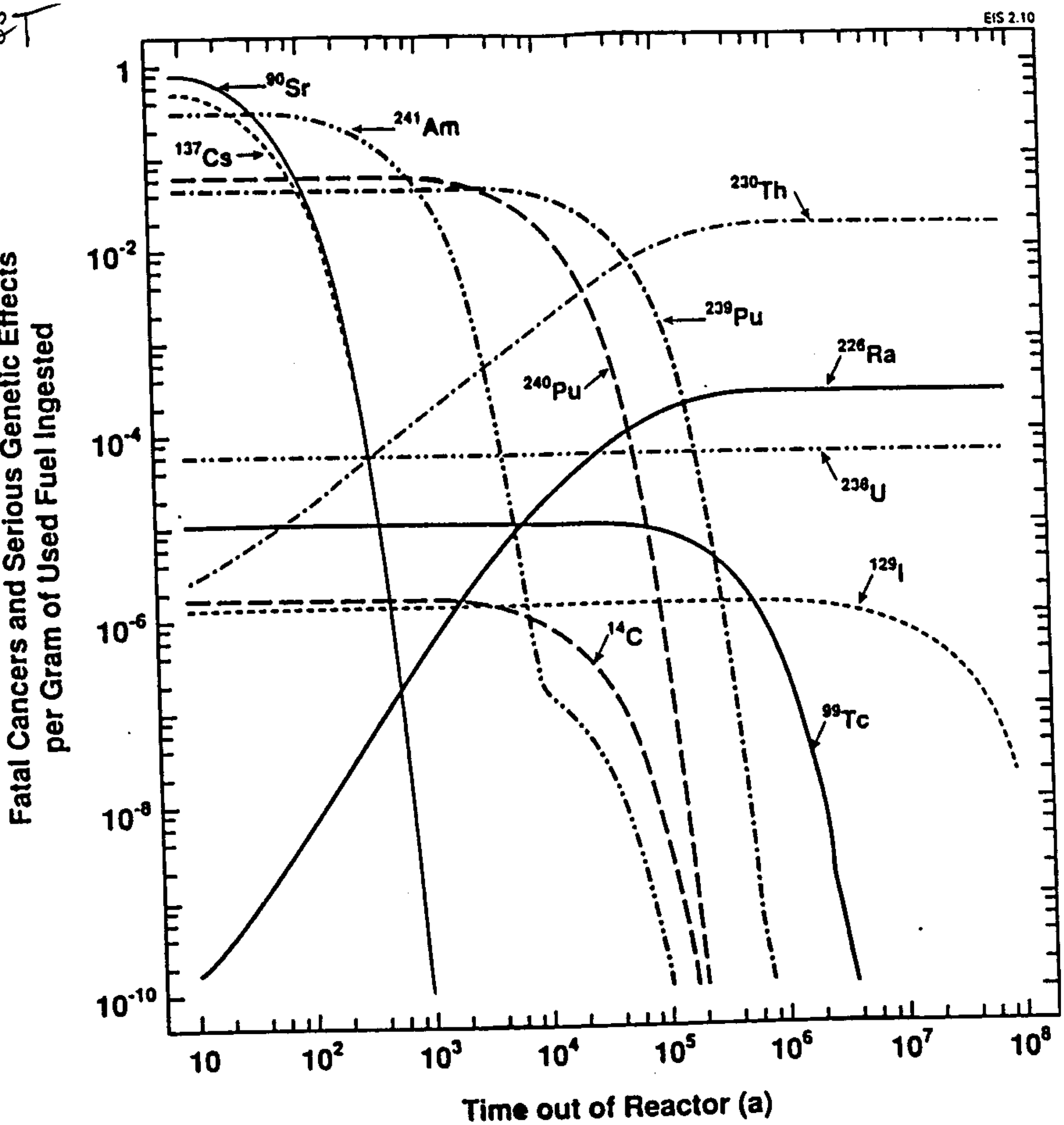


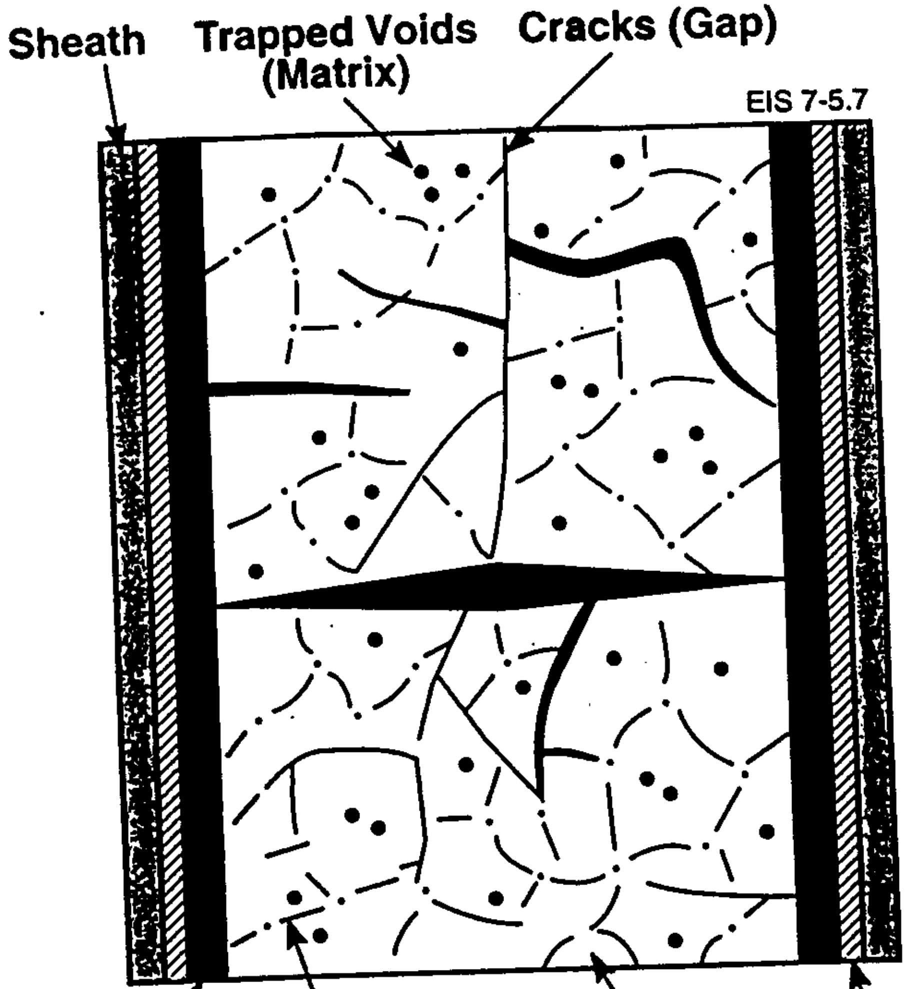
FIGURE 2-7: HEAT FROM THE USED FUEL SPECIFIED FOR THE CASE STUDIES (LOGARITHMIC SCALES)

FDAH

RDGT



'IGURE 2-10: RADIOTOXICITY OF VARIOUS RADIONUCLIDES IN USED CANDU F



Gap	Grain Boundary	UO_2 Matrix	CANLUB
^{14}C	^{14}C	Actinides ~98% Fission Products	^{14}C
^{129}I	^{129}I		
^{135}Cs	^{135}Cs		
^{79}Se	^{79}Se		
^{125}Sn	^{99}Tc		
^{3}H	^{125}Sn		
	^{107}Pd		
	^{3}H		

Conceptual Distribution of Some Fission and Activation Products Within a Used-Fuel Element

CDG

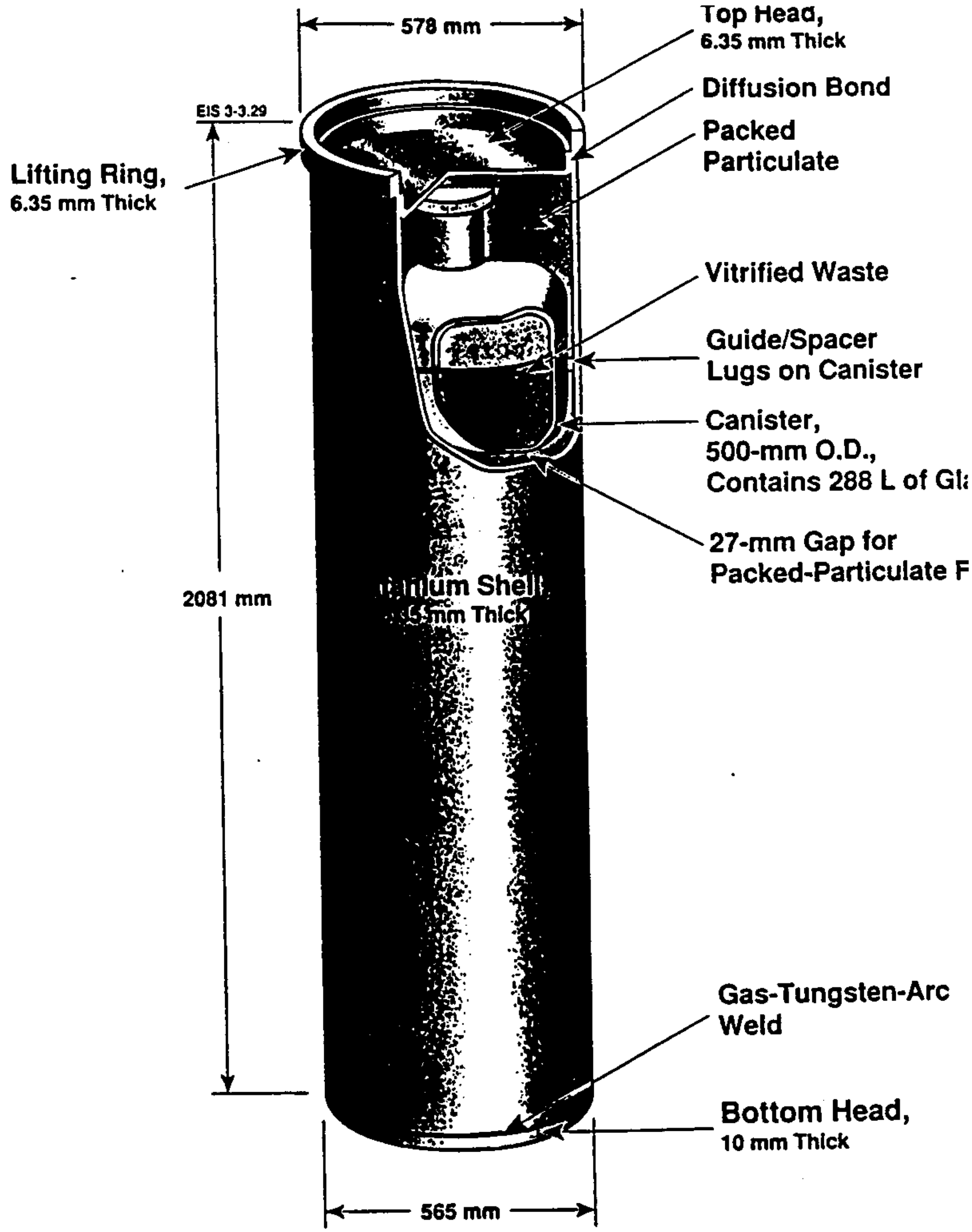
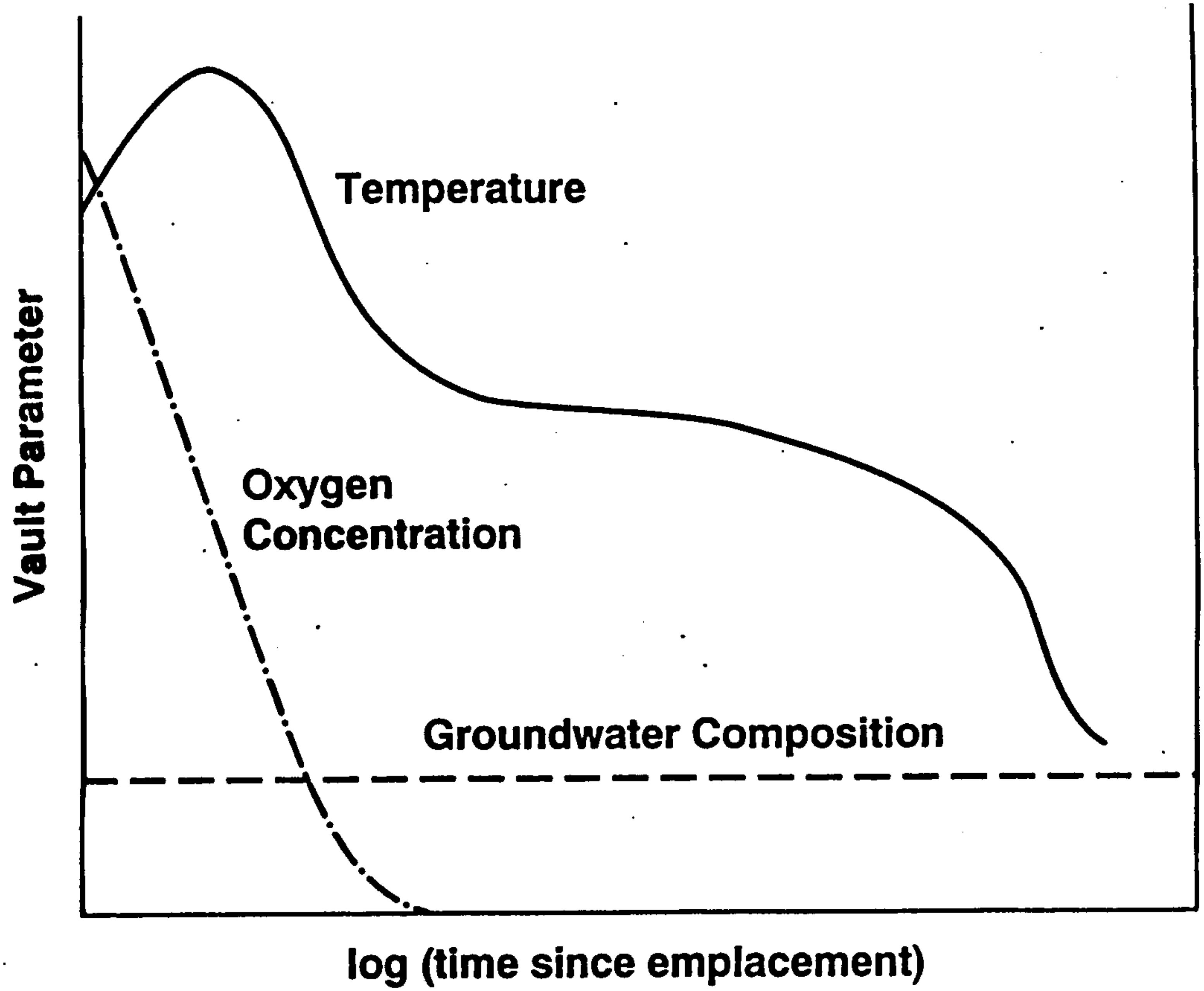


FIGURE 3-29: Titanium-Shell, Fuel-Reprocessing-Waste Disposal Cont
with Vitrified-Waste Canister

CDG



; 4-8a: Expected Changes in Those Vault Parameters That Would Affec

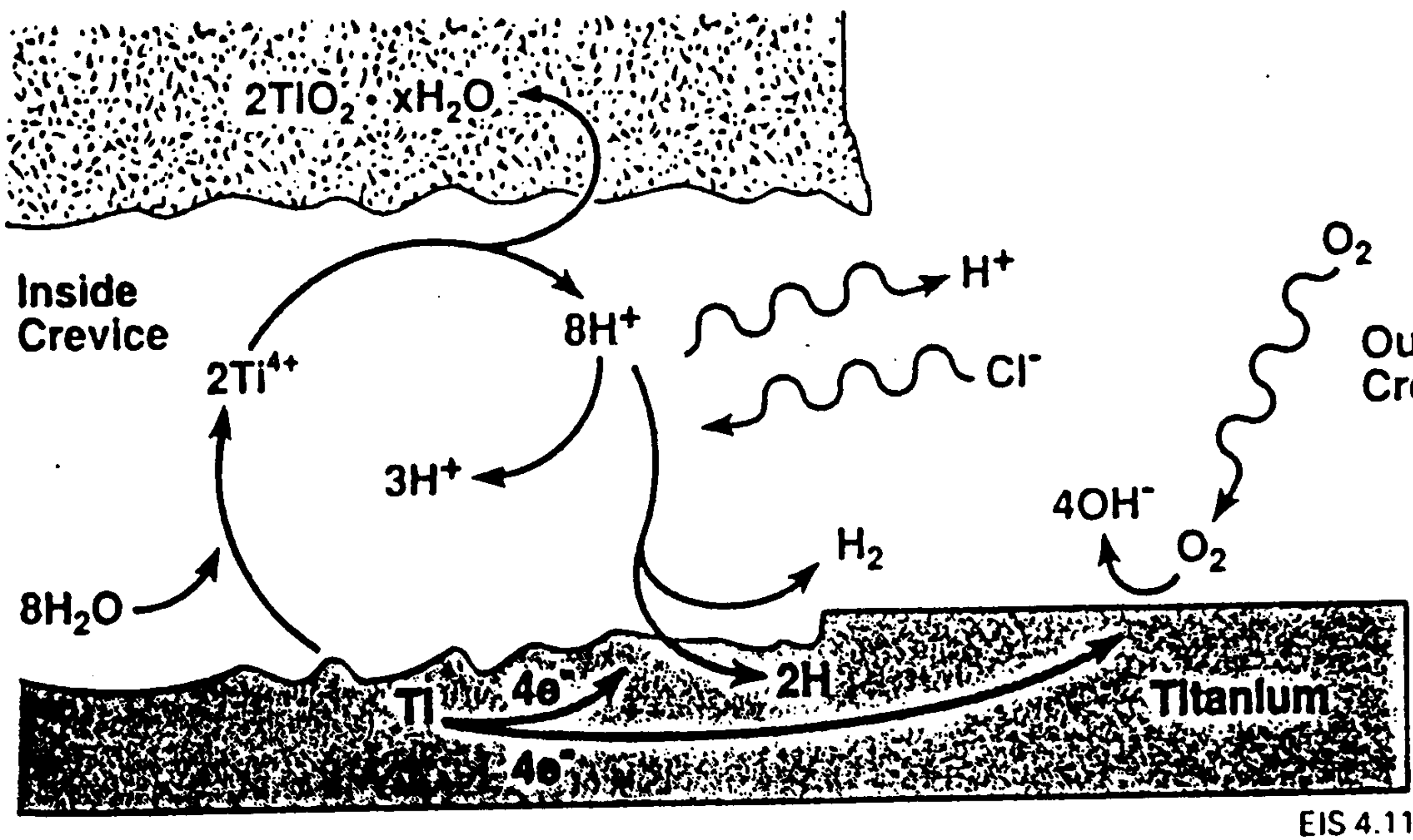
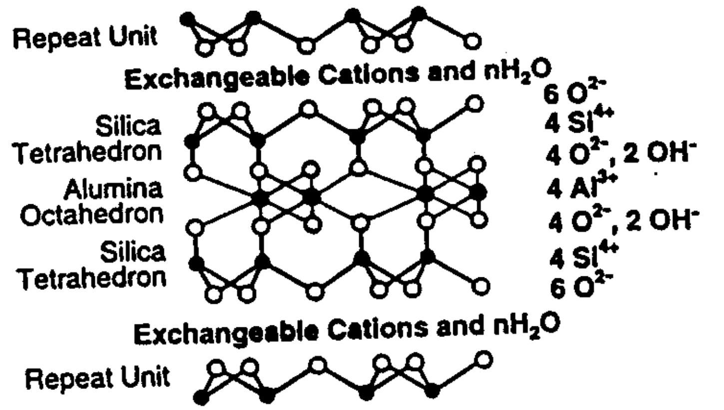
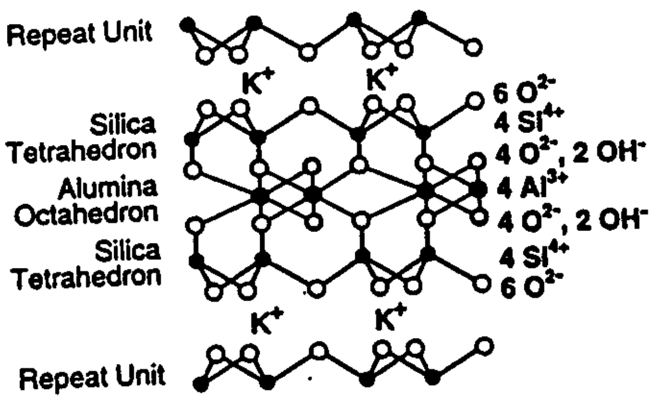


FIGURE 4-11: SCHEMATIC SHOWING THE BASIC ELECTROCHEMICAL, CHEMICAL, AND TRANSPORT STEPS INVOLVED IN THE CREVICE



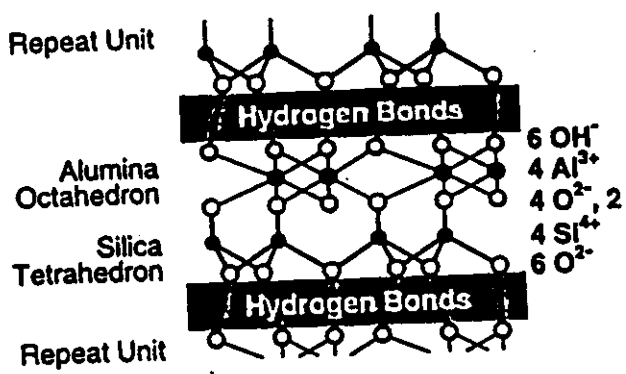
Montmorillonite Crystal Structure

Isomorphous substitutions and imperfections in the crystal lattice give high negative charge. (Cation exchange capacity = 80 meq/100 g, specific surface area = 600 m^2/g.)



Illite Crystal Structure

Structure is similar to montmorillonite; potassium ions bond the silica-alumina layers. Crystal size is greater and surface activity is less than that of montmorillonite. (Cation exchange capacity = 20 meq/100 g, specific surface area = 80 m^2/g.)



Kaolinite Crystal Structure

Kaolinite has the lowest surface activity and largest crystal size. (Cation exchange capacity = 5 meq/100 g, specific surface area = 20 m^2/g.)

FIGURE 4-3: Crystal Structures of Some Common Clay Minerals (after Lamb and Whitman 1969)

BDGS

VDG

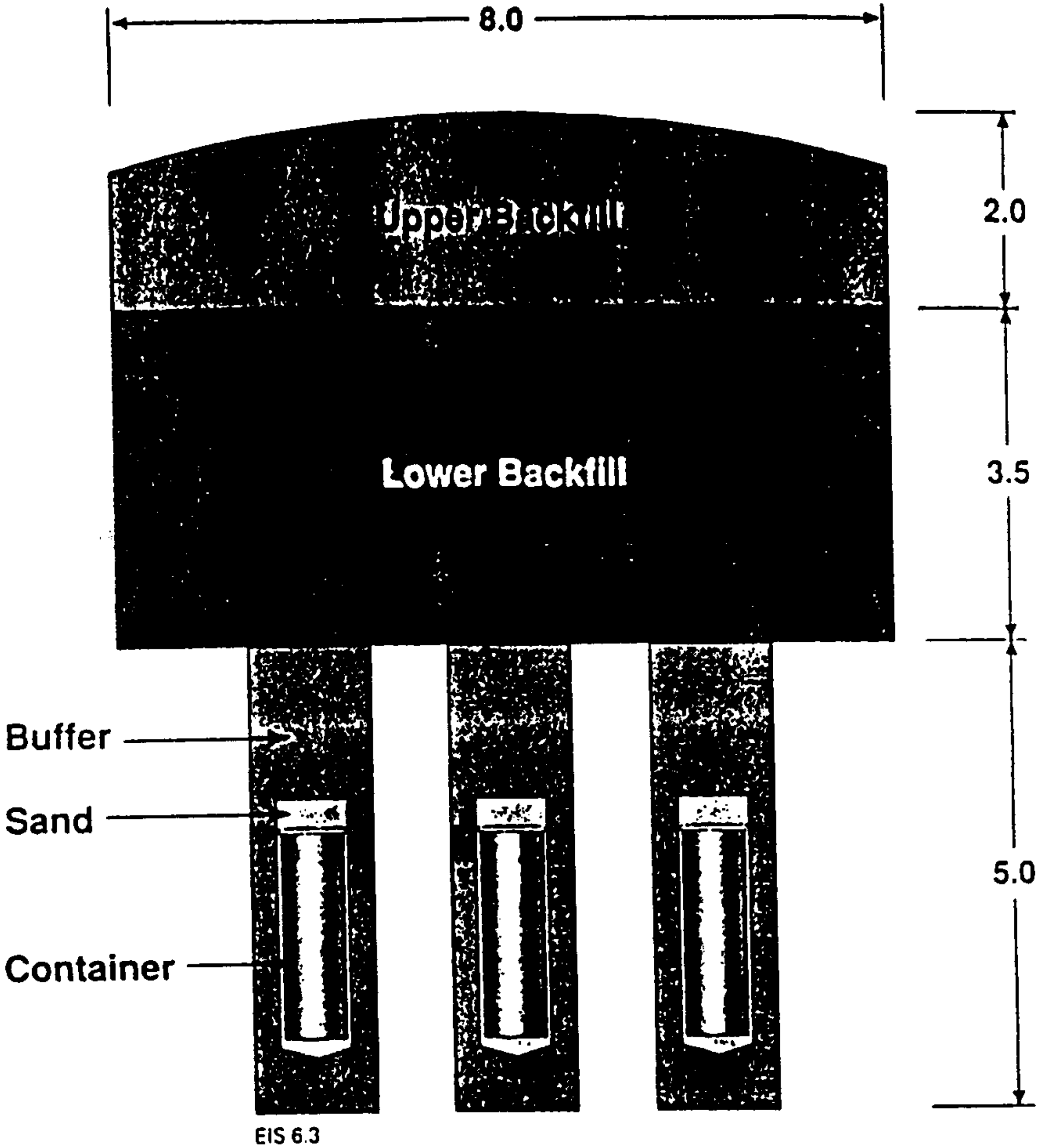
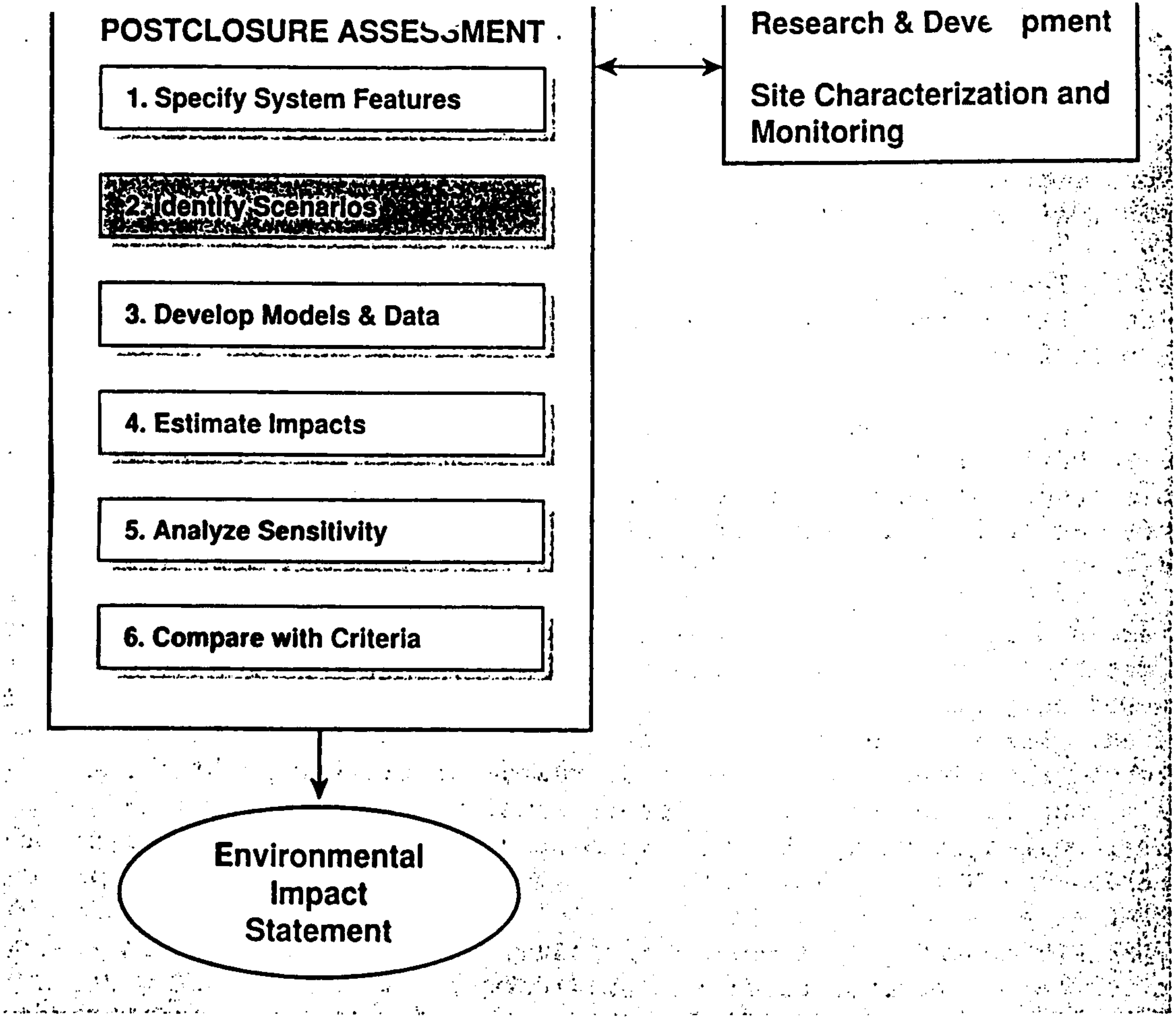


FIGURE 6-3: CROSS SECTION OF A FILLED DISPOSAL ROOM IN THE PREDISPOSAL-FACILITY

VDG

AT


POSTCLOSURE ASSESSMENT
1. Specify System Features
2. Identify Scenarios
3. Develop Models & Data
4. Estimate Impacts
5. Analyze Sensitivity
6. Compare with Criteria
Research & Development
Site Characterization and Monitoring
Environmental Impact Statement

HM

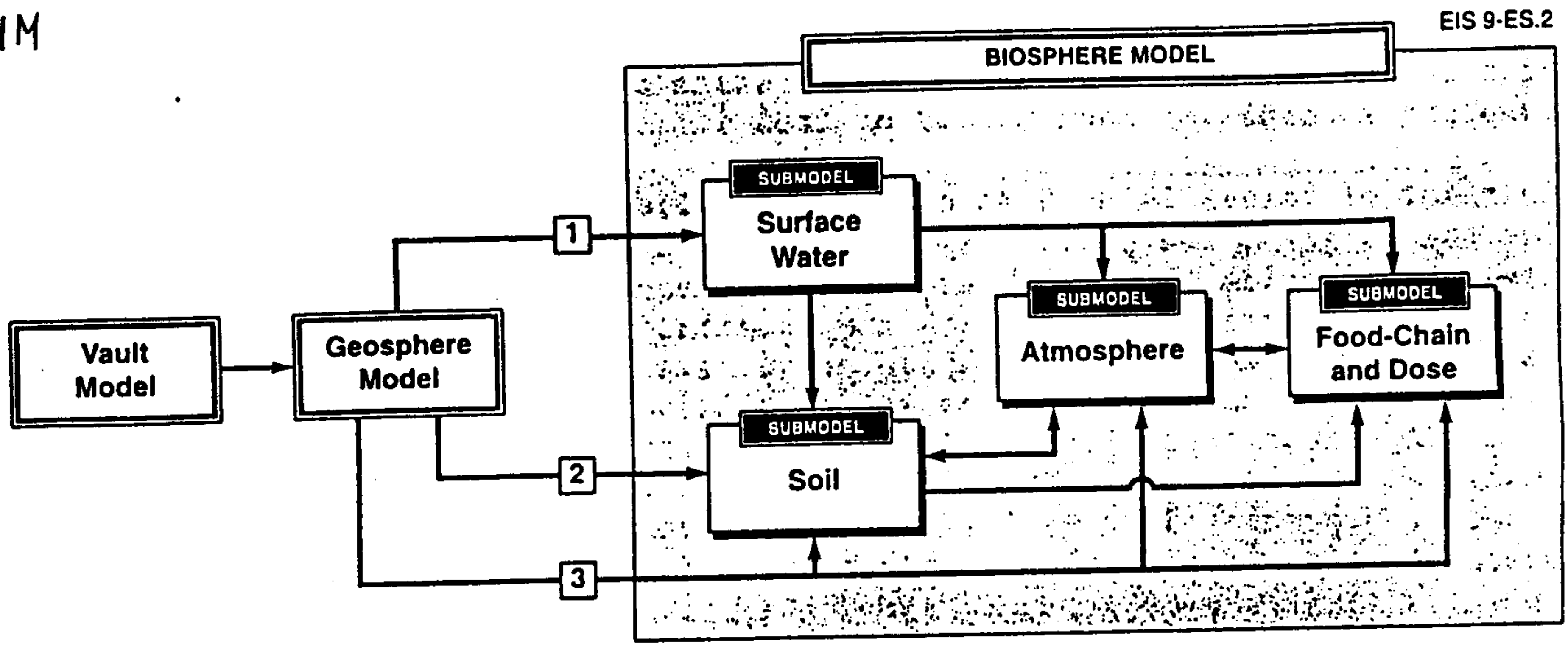
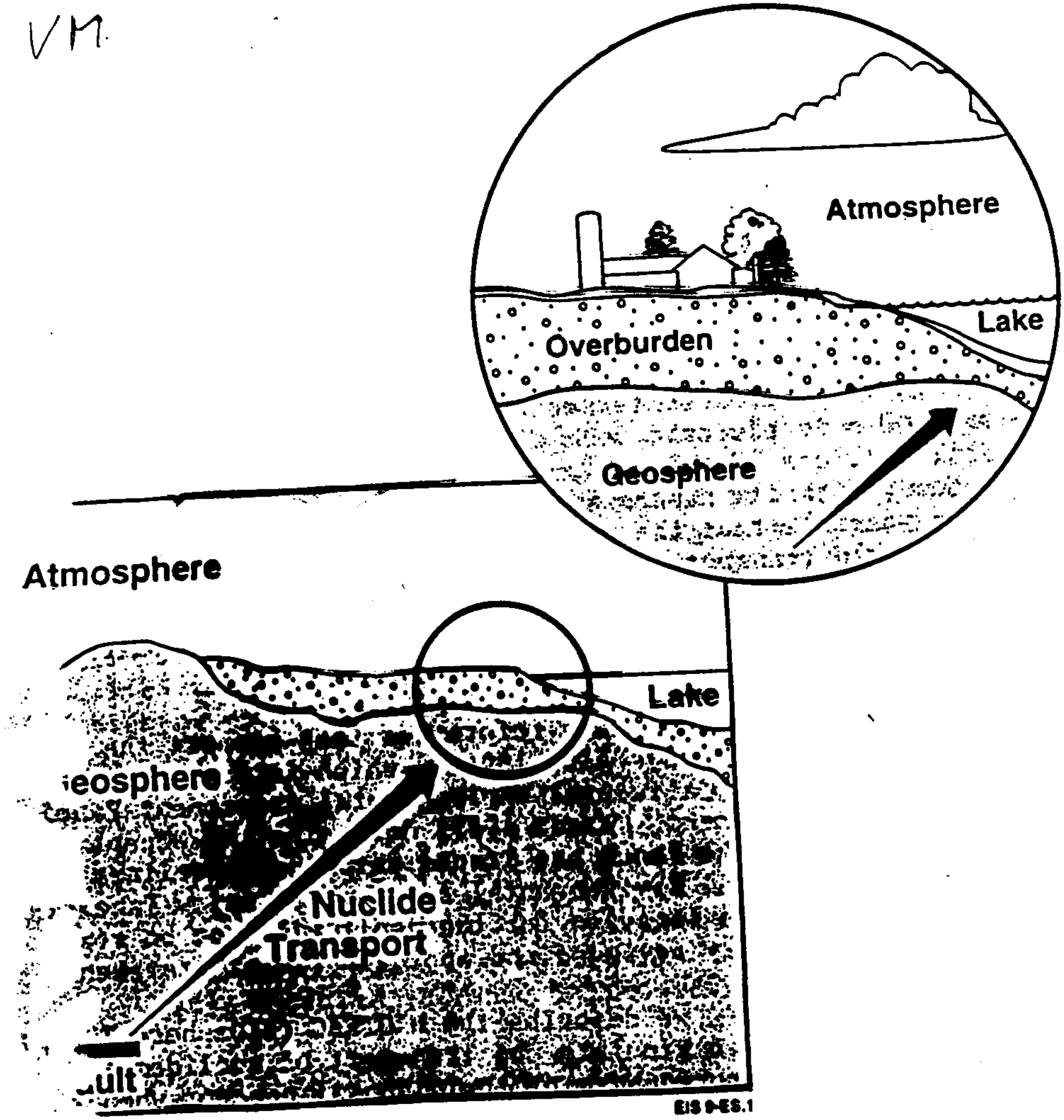


FIGURE ES-2: Schematic Representation of the Three Main Assessment Models (Vault, Geosphere and Biosphere) for the Disposal Concept Assessment, and of the Main Nuclide Transfers Among the Four Submodels of the Biosphere Model (Surface Water, Soil, Atmosphere, and Food-Chain and Dose) and Between the Geosphere and Biosphere Models. Discharges from the geosphere to the biosphere model are: (1) aquatic, (2) terrestrial and (3) well.

VM



Schematic Representation of Groundwater Transport of Nucli from the Vault, 500 to 1000 m Underground, to the Biospher (Enlarged Insert)

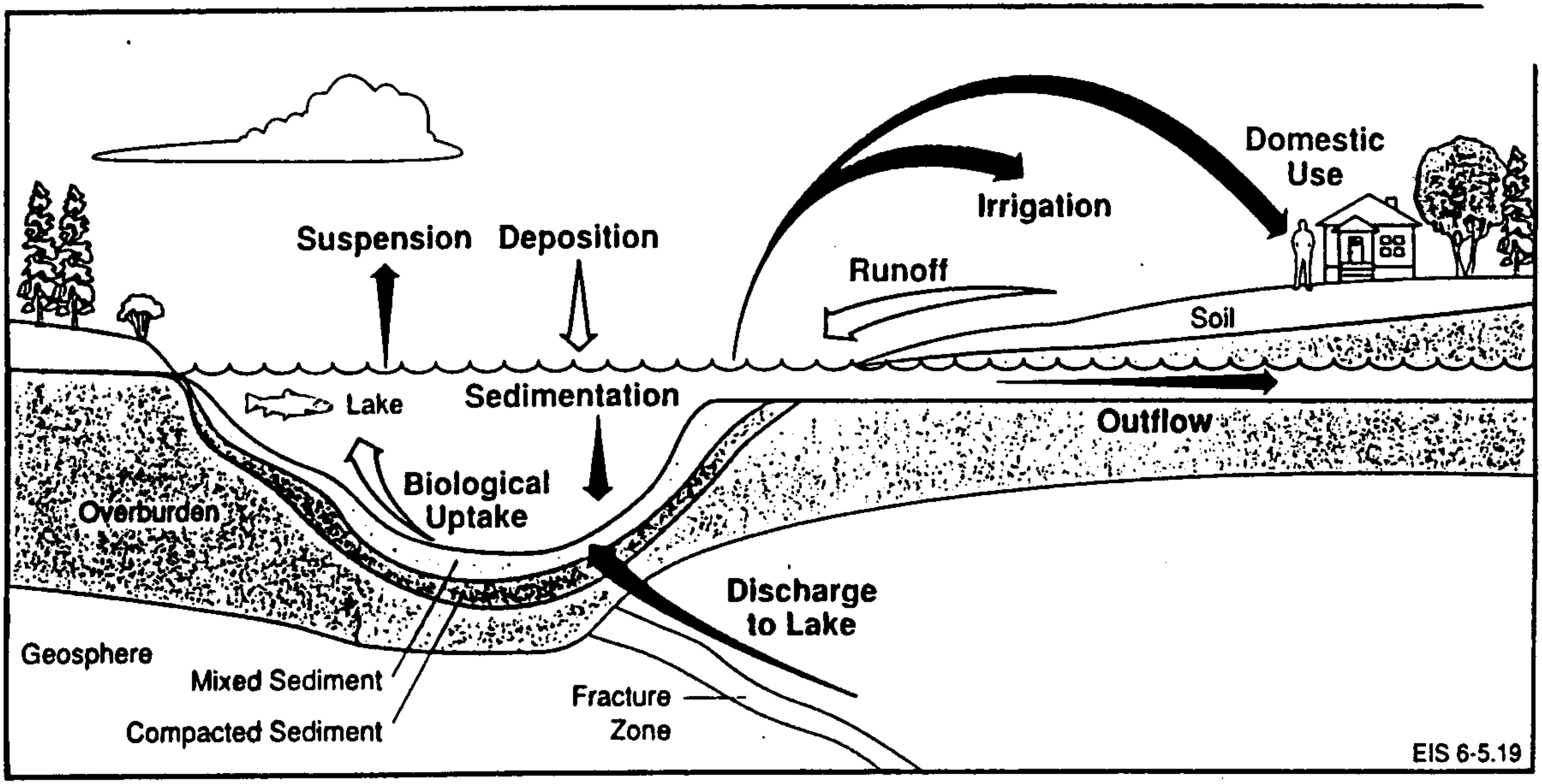


FIGURE 5-19: The Processes Modelled in the Lake and Lake Sediments Model

The solid arrows show processes that are explicitly modelled in the surface water model and the open arrows indicate processes that are implicitly considered (Davis et al. 1993). The primary sources of contaminants are the well (not shown) and groundwater discharging through the overburden to the compacted sediments (these sediments underlie Pinawa Channel and Boggy Creek shown in Figure 5-16). Contaminants leave the lake water by radioactive decay (not illustrated), particle suspension and degassing to the atmosphere, sedimentation to the mixed sediments, pumping for domestic and irrigation use by the critical group, and outflow downstream. We assume that all contaminants eventually return to the lake, except those lost by radioactive decay, outflow, and (for ^{14}C and the noble gases) by degassing.

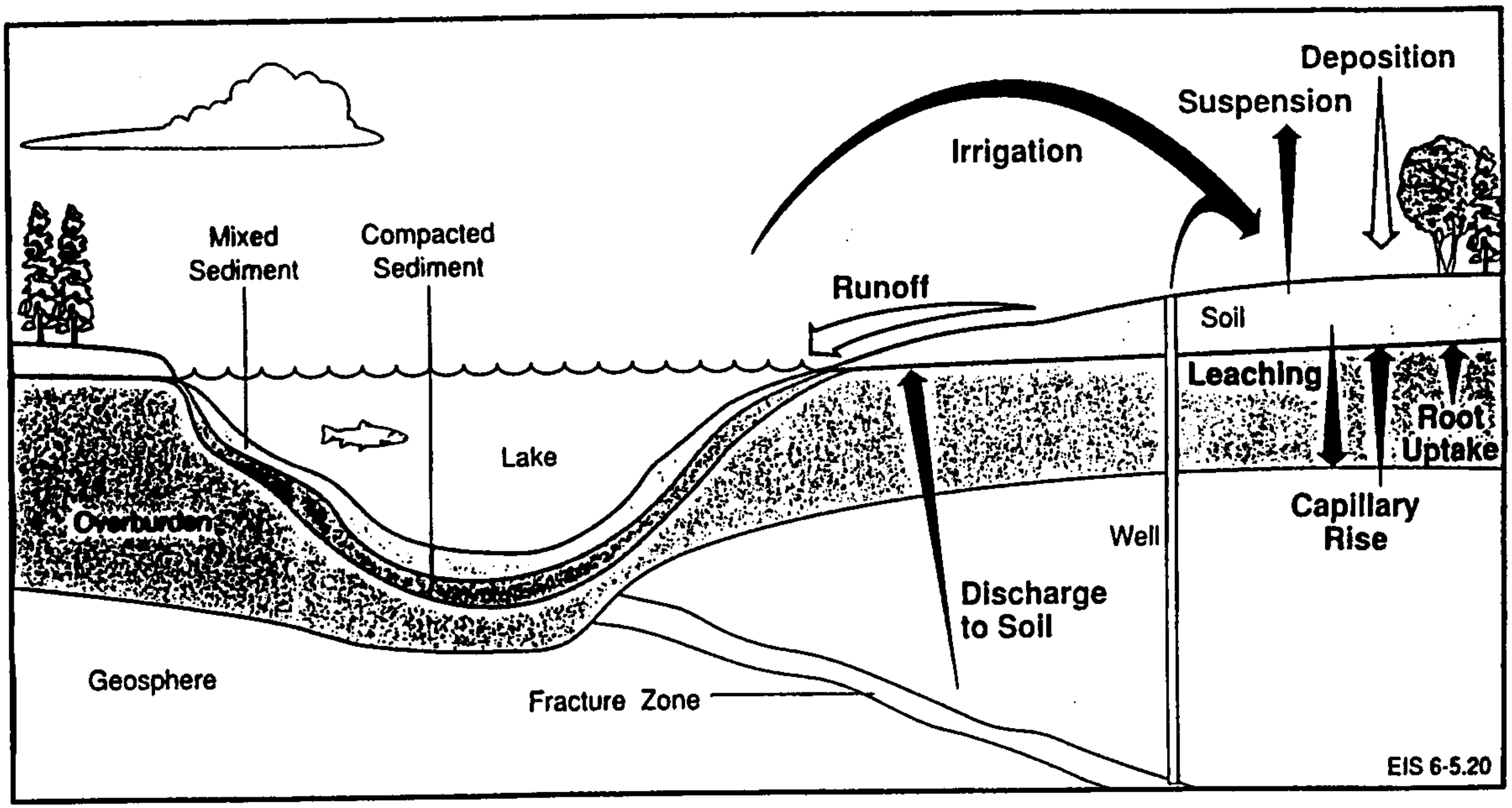
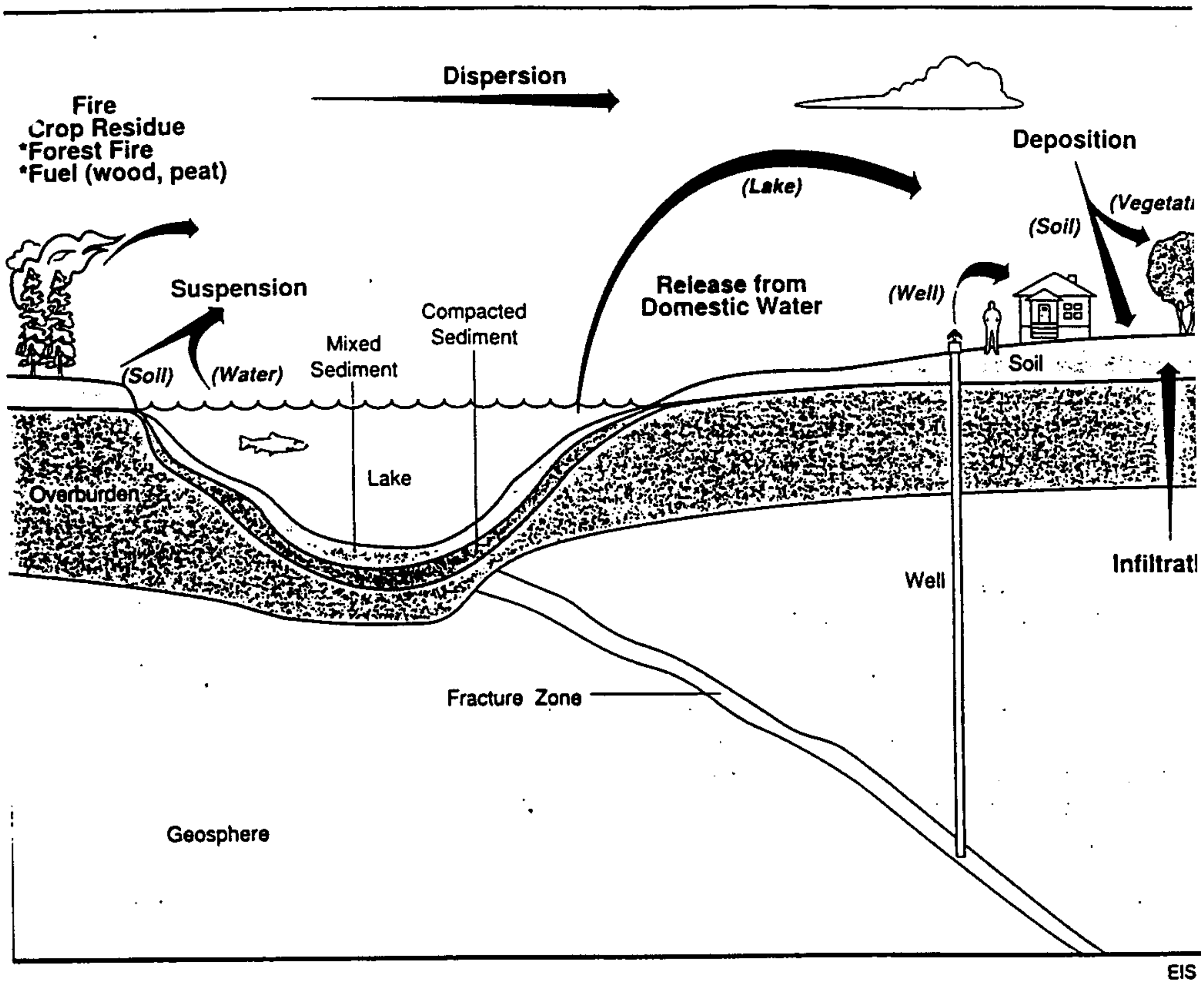


FIGURE 5-20: The Processes Modelled in the Soil Model

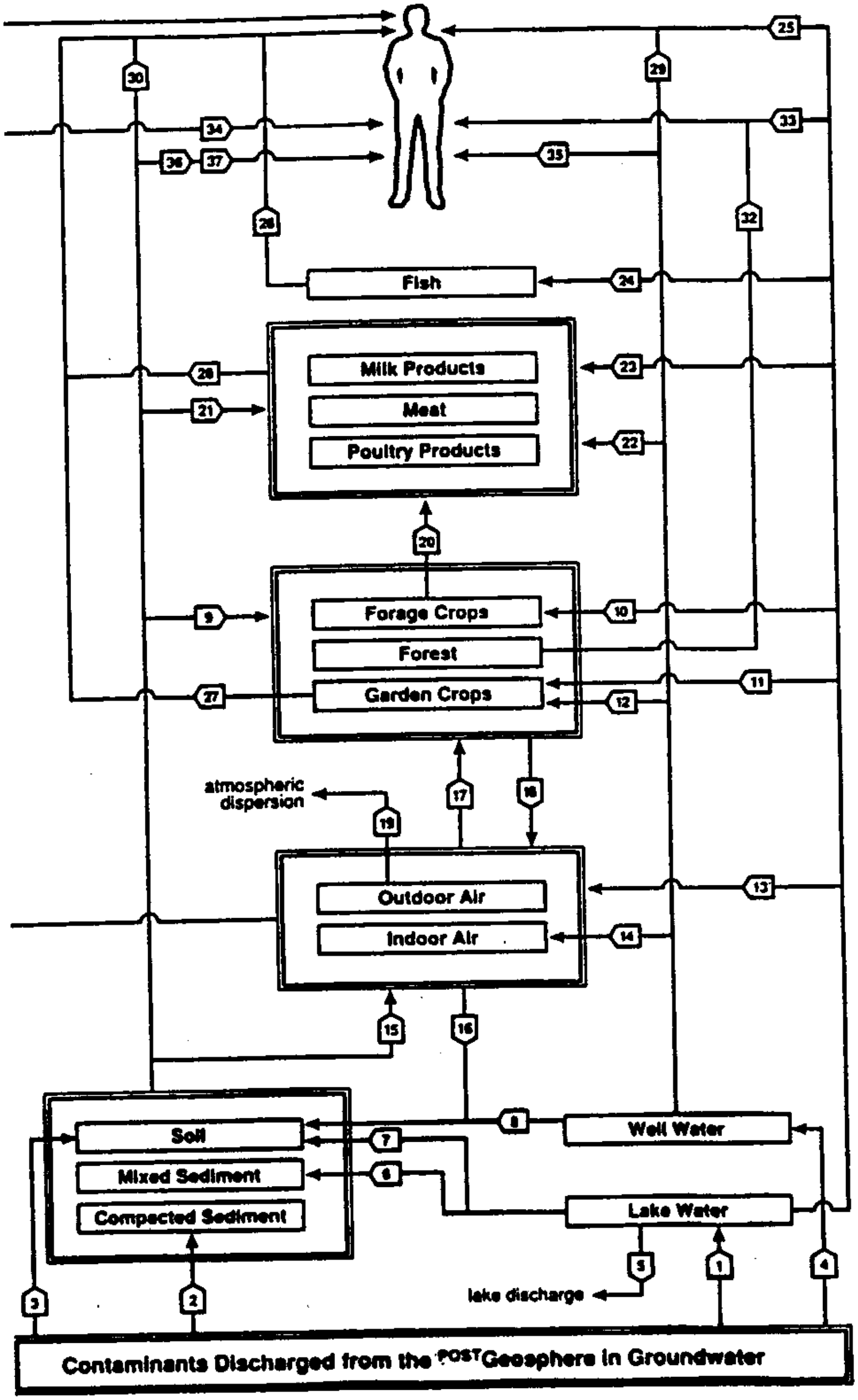
The solid arrows show processes that are explicitly modelled in the soil model, and the open arrows indicate processes that a implicitly considered (Davis et al. 1993). Four fields are modelled in a similar manner: a garden, a forage field, a woodlot anc peat bog (shown in Figure 5-16). Contaminants enter each field by capillary rise from the water table below the soil, by air deposition of contaminants, and (for the garden and forage field only) by irrigation using water from the lake or well. Contaminants leave each area by leaching, suspension, root uptake, and runoff to the lake.



HMA

FIGURE 5-21: The Processes Modelled in the Atmosphere Model

The arrows show processes that are explicitly modelled in the atmosphere model (Davis et al. 199: Contaminants enter outside air by degassing and suspension of particulates from the soil in the fields, from the water of the lake and from fires (including burning wood and peat for fuel). Contaminants enter dwellings with the outside air, by releases from domestic water (from the lake and the well), and by infiltration from soil around building foundations. We assume that the contaminants are well mixed by dispersion in the air.



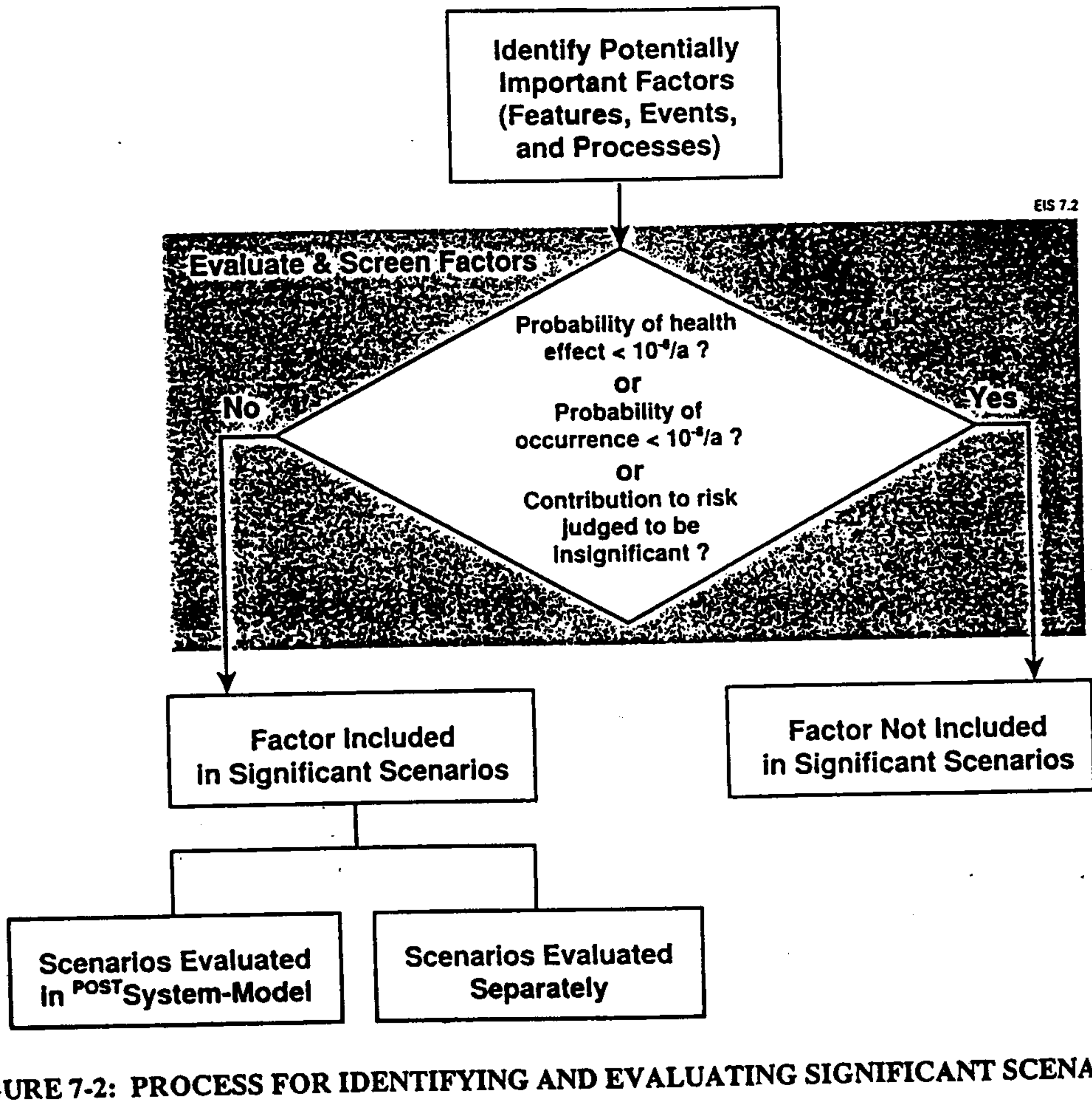
1 Geosphere discharge to lake water
2 Geosphere discharge to compacted sediment
3 Geosphere discharge to bottom of soil profile
4 Geosphere discharge to well water
5 Loss through lake discharge
6 Transfer from lake water to mixed sediment
7 Transfer from lake water to soil (irrigation)
8 Transfer from well water to soil (irrigation)
9 Transfer from soil/sediments to plants (root uptake)
10 Transfer from lake water to leaves of forage crops (irriga
11 Transfer from lake water to leaves of garden crops (irrig
12 Transfer from well water to leaves of garden crops (irrig
13 Transfer from lake water to air
14 Transfer from well water to indoor air
15 Transfer from soil/sediments to air
16 Transfer from air to soil (deposition)
17 Transfer from air to plant leaves (deposition)
18 Transfer from plants to air
19 Loss through atmospheric dispersion
20 Transfer from forage crops to milk products, meat, and p
21 Transfer from soil/sediments to milk products, meat, and
22 Transfer from well water to milk products, meat, and pou
23 Transfer from lake water to milk products, meat, and pou
24 Transfer from lake water to fish
25 Transfer from lake water to man (ingestion)
26 Transfer from fish to man (ingestion)
27 Transfer from garden crops to man (ingestion)
28 Transfer from milk products, meat, and poultry products
29 Transfer from well water to man (ingestion)
30 Transfer from soil/sediments to man (ingestion)
31 Transfer from air to man (inhalation)
32 External exposure of man to wooden building materials
33 External exposure of man to lake water
34 External exposure of man to air
35 External exposure of man to well water
36 External exposure of man to soil/sediments
37 External exposure of man to inorganic building material

EIS 7.5

FIGURE 7-5: COMPARTMENTS AND PATHWAYS IN THE POST BIOSPHERE-MODEL

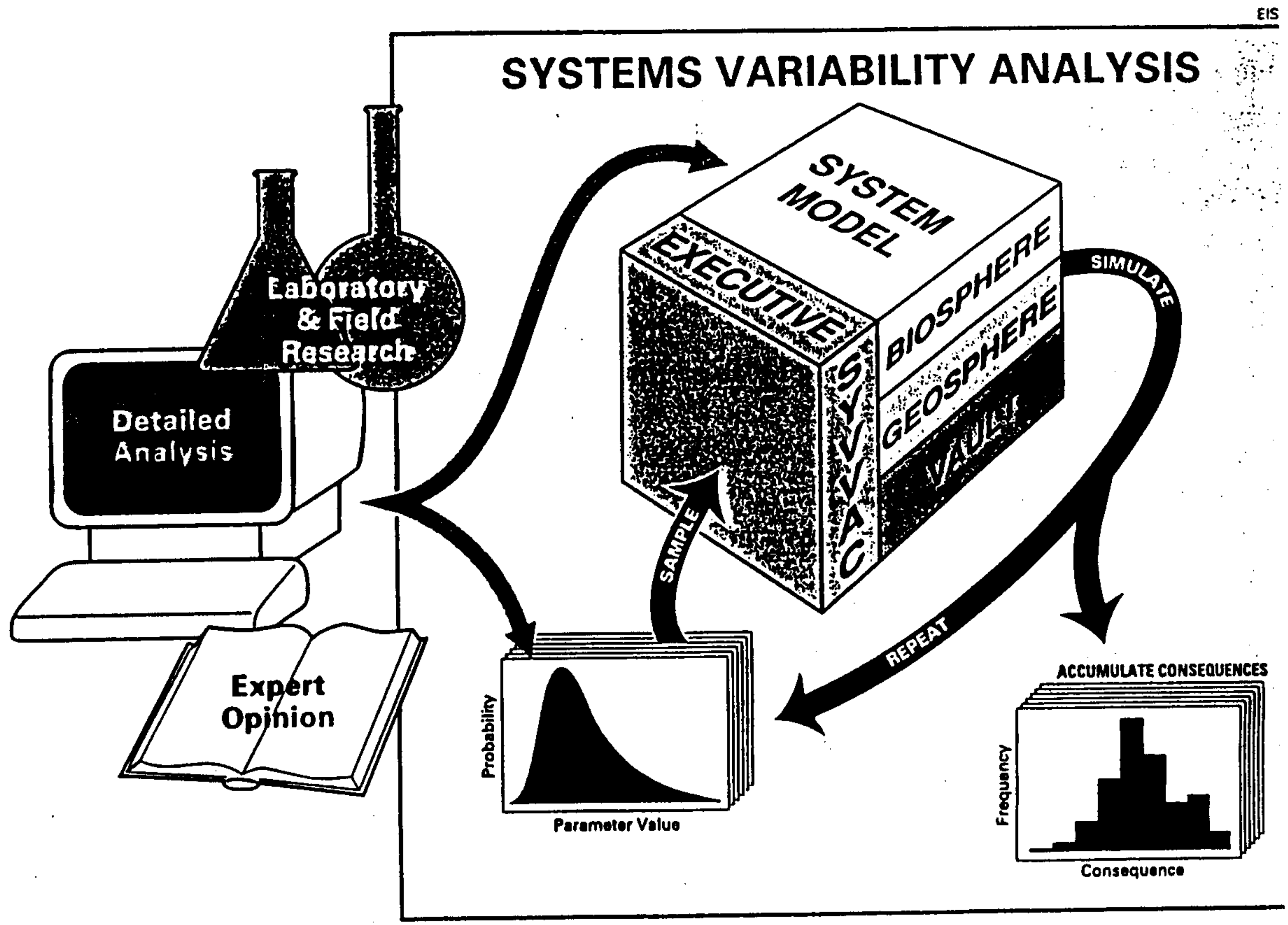
AMB

4A



URE 7-2: PROCESS FOR IDENTIFYING AND EVALUATING SIGNIFICANT SCENAR

^A1


EIS
SYSTEMS VARIABILITY ANALYSIS
SYSTEM MODEL
EXECUTIVE
BIOSPHERE
GEOSPHERE
VAULT
SYVAC
SIMULATE
SAMPLE
REPEAT
Detailed Analysis
Laboratory & Field Research
Expert Opinion
Probability
Parameter Value
ACCUMULATE CONSEQUENCES
Frequency
Consequence

DDG

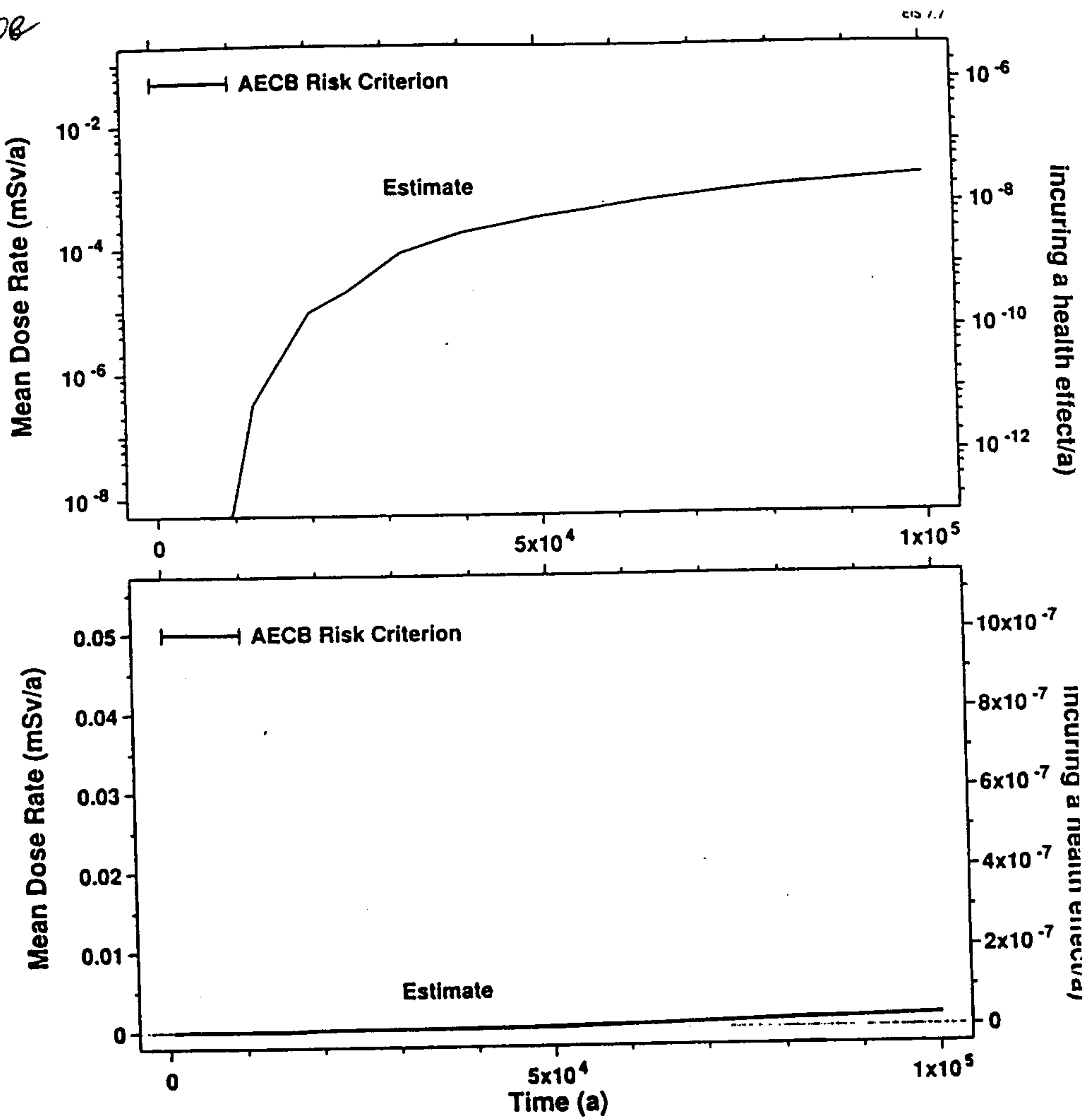


FIGURE 7-7: ESTIMATED MEAN DOSE RATE AND RISK AS A FUNCTION OF TI

DDG

DD1F

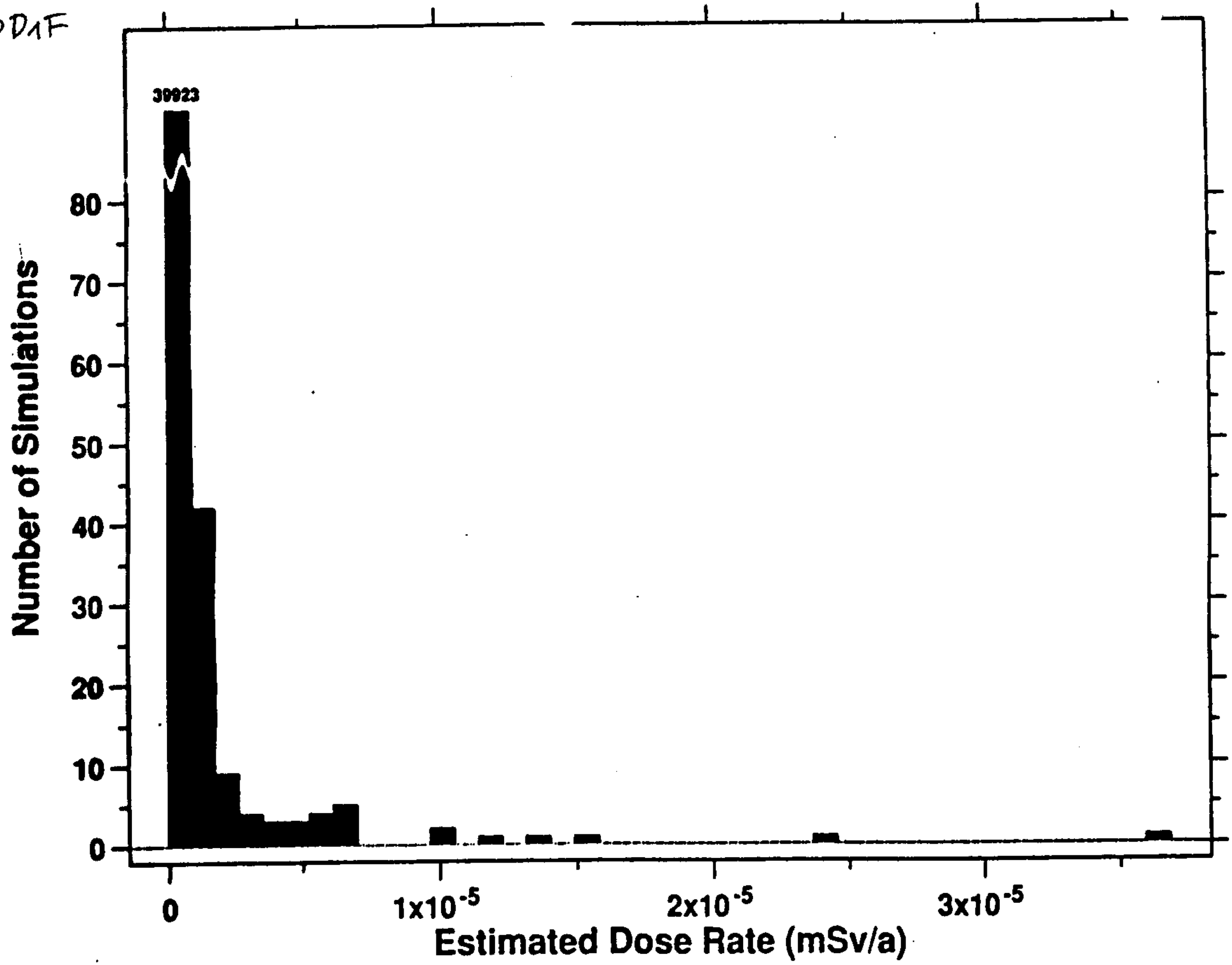


FIGURE 7-8: ESTIMATED DOSE RATES AT 10 000 YEARS

DD

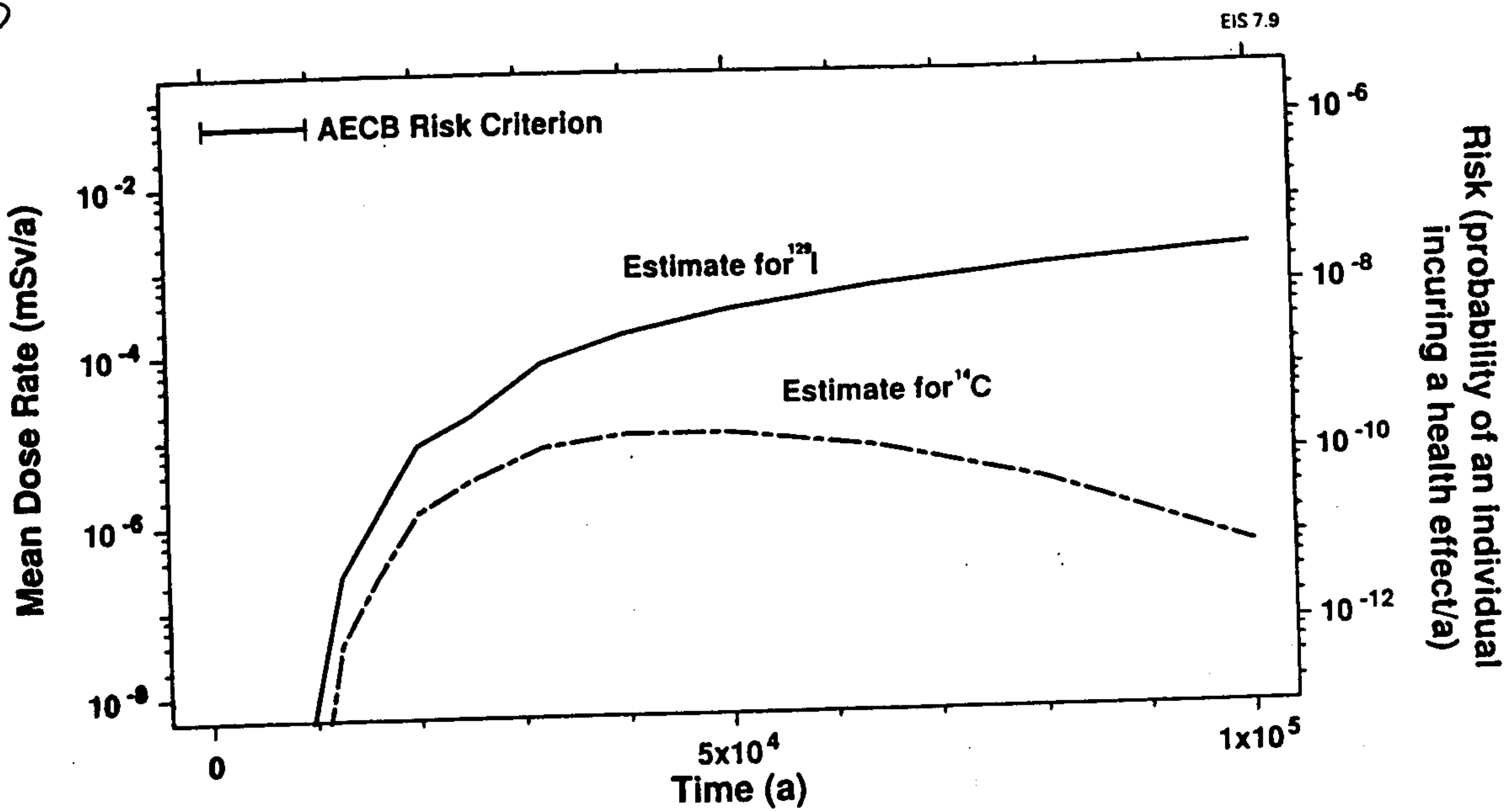


FIGURE 7-9: CONTRIBUTIONS OF ^{129}I AND ^{14}C TO THE ESTIMATED MEAN DOSE RATE AND RISK

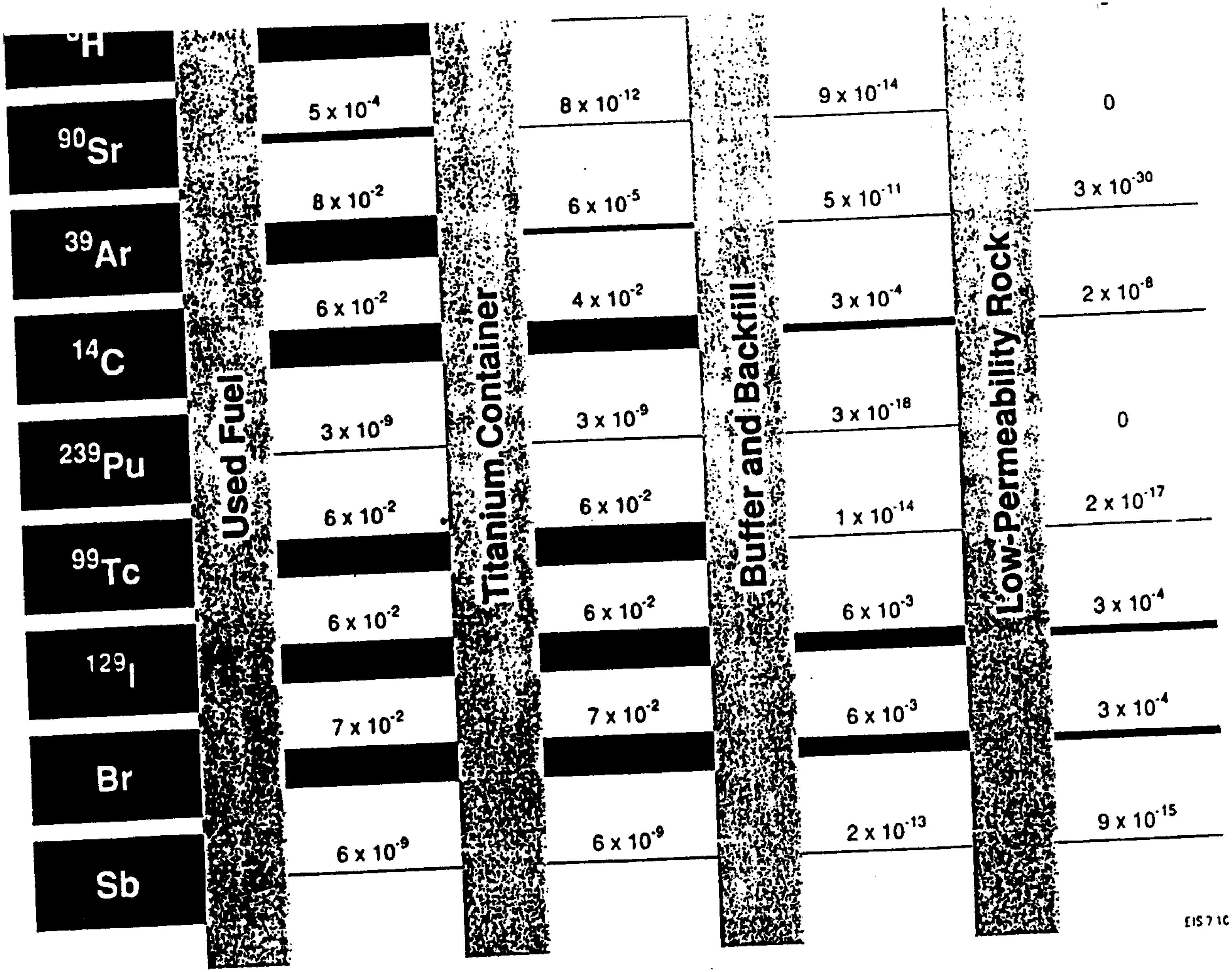


FIGURE 7-10: CUMULATIVE FRACTION OF A NUCLIDE RELEASED BY THE BARRIERS