Environmental Issues in Waste Management

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Introduction

- Objectives of environmental work
- History of radioecology
- Issues related to waste management
- Overview of international programs

Processes in the Biosphere

- Discharge to the biosphere
- Lakes and rivers
- Soil
- Atmosphere
- Human realm
- Natural realm

Models of the Biosphere

- General issues
- Discharge model
- Lake and river models
- Soil models
- Atmospheric models
- Food Chain and dose models
- Models for non-human
- Alternative models

Parameters for Models and Use of Models

Probability density functions

Truncations, correlations

Sources of data

Sensitivity analysis

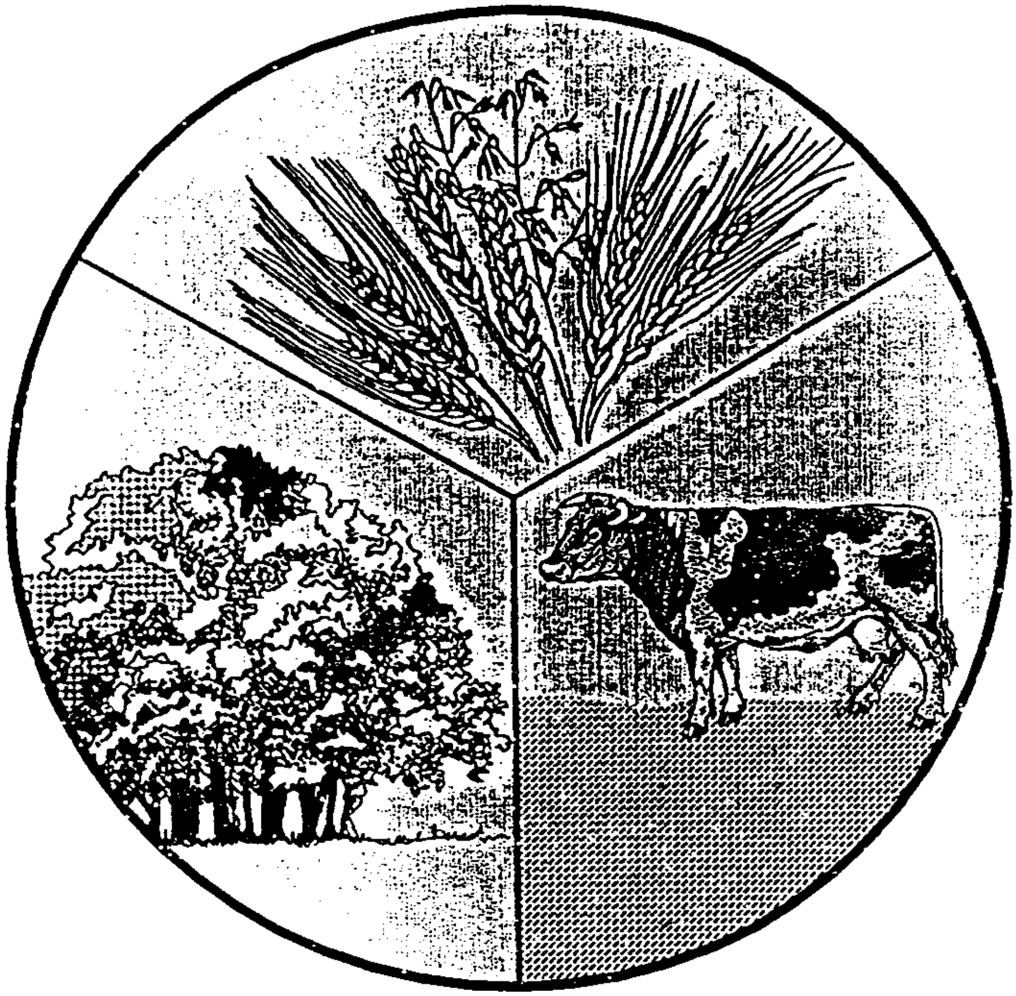
Model simplification

New Issues, Research Opportunities, International Programs

- Dose to non-human biota
- Population doses
- Chemical toxicity
- Landscape models
- International biosphere programs

Objectives of Environmental Work

- Compute an endpoint consistent with regulations
- Communicate with the public
- Optimization ... a standard of measure
- Siting issues
- Dose reconstruction



TECHNICAL REPORTS SERIES No. 363

Guidelines for Agricultural Countermeasures Following an Accidental Release of Radionuclides

A JOINT UNDERTAKING BY THE IAEA AND FAO

History of Radioecology

Predict effects of nuclear war

Predict effects of civilian nuclear facilities

Predict effects of waste management

Tremendous amount of data for Cesium and for short term effects

TABLE 6

ELEMENT-SPECIFIC GEOMETRIC MEANS (GM) OF THE LOGNORMAL PROBABILITY DENSITY FUNCTIONS FOR THE CONCENTRATION RATIO (Bv_i) AND TRANSFER COEFFICIENTS (F_{ij} AND B_{ij}) FOR CONCEPT ASSESSMENT

	Bv_i	F_{ij}			B_{ij}
Element	Plant/Soil	TE MILK	TE MEAT	TE BIRD	FW FISH
Ac	8.8 x 10^{-4}	2.0 x 10^{-5}	2.5 x 10^{-5}	2.5 x 10^{-3}*	2.5 x 10^{1}
Am	1.4 x 10^{-3}	4.1 x 10^{-7}	3.5 x 10^{-6}	8.5 x 10^{-3}	1.0 x 10^{2}
Ar	0.0	0.0	0.0	0.0	0.0
Be	2.5 x 10^{-3}	9.1 x 10^{-7}	1.0 x 10^{-3}	1.0 x 10^{-1}*	2.0 x 10^{0}
Bi	8.8 x 10^{-3}	5.0 x 10^{-4}	4.0 x 10^{-4}	4.0 x 10^{-2}*	1.5 x 10^{1}
Br	3.8 x 10^{-1}	2.0 x 10^{-2}	2.5 x 10^{-2}	2.5 x 10^{0}*	4.2 x 10^{2}
C	5.5 x 10^{0} **	1.5 x 10^{-2}	6.4 x 10^{-2}	6.4 x 10^{0}*	5.0 x 10^{4}
Ca	8.8 x 10^{-1}	1.1 x 10^{-2}	1.6 x 10^{-3}	4.4 x 10^{-1}	4.0 x 10^{1}
Cd	1.4 x 10^{-1}	1.5 x 10^{-3}	3.5 x 10^{-4}	8.4 x 10^{-1}	2.0 x 10^{2}
Cr	1.9 x 10^{-3}	1.1 x 10^{-3}	9.2 x 10^{-3}	9.2 x 10^{-1}*	2.0 x 10^{2}
Cs	2.0 x 10^{-2}	7.1 x 10^{-3}	2.6 x 10^{-2}	4.4 x 10^{0}	1.0 x 10^{4}
H***					
Hf	8.8 x 10^{-4}	5.0 x 10^{-6}	1.0 x 10^{-3}	1.0 x 10^{-1}*	3.3 x 10^{0}
I	3.8 x 10^{-2}****	9.9 x 10^{-3}	7.0 x 10^{-3}	2.8 x 10^{0}	5.0 x 10^{1}
K	2.5 x 10^{-1}	7.2 x 10^{-3}	1.8 x 10^{-2}	1.8 x 10^{0}*	1.0 x 10^{3}
Kr	0.0	0.0	0.0	0.0	0.0
Mo	6.3 x 10^{-2}	1.4 x 10^{-3}	6.8 x 10^{-3}	5.0 x 10^{-1}	1.0 x 10^{1}
Nb	5.0 x 10^{-3}	2.0 x 10^{-2}	2.5 x 10^{-1}	3.0 x 10^{-3}	1.0 x 10^{2}
Ni	1.5 x 10^{-2}	1.0 x 10^{-3}	2.0 x 10^{-3}	2.0 x 10^{-1}*	1.0 x 10^{2}
Np	2.5 x 10^{-2}	5.0 x 10^{-6}	5.5 x 10^{-5}	5.5 x 10^{-3}*	2.5 x 10^{3}
P	8.8 x 10^{-1}	1.6 x 10^{-2}	4.9 x 10^{-2}	4.9 x 10^{0}*	6.7 x 10^{4}
Pa	6.3 x 10^{-4}	5.0 x 10^{-6}	1.0 x 10^{-5}	1.0 x 10^{-3}*	1.1 x 10^{1}
Pb	1.1 x 10^{-2}	2.6 x 10^{-4}	4.0 x 10^{-4}	4.0 x 10^{-2}*	3.0 x 10^{2}
Pd	3.8 x 10^{-2}	1.0 x 10^{-2}	4.0 x 10^{-3}	4.0 x 10^{-1}*	1.0 x 10^{1}
Po	6.3 x 10^{-4}	3.4 x 10^{-4}	4.5 x 10^{-3}	4.5 x 10^{-1}*	5.0 x 10^{2}
Pu	1.1 x 10^{-4}	1.0 x 10^{-7}	2.0 x 10^{-6}	7.6 x 10^{-3}	2.5 x 10^{2}
Ra	3.3 x 10^{-3}	4.0 x 10^{-4}	9.0 x 10^{-4}	9.0 x 10^{-2}*	5.0 x 10^{1}
Rb	3.8 x 10^{-2}	1.2 x 10^{-2}	1.1 x 10^{-2}	1.1 x 10^{0}*	2.0 x 10^{3}
Re	3.8 x 10^{-1}	1.3 x 10^{-3}	8.0 x 10^{-3}	8.0 x 10^{-1}*	1.2 x 10^{2}
Rn	0.0	0.0	0.0	0.0	0.0
Sb	5.0 x 10^{-2}	1.1 x 10^{-4}	1.0 x 10^{-3}	1.0 x 10^{-1}*	2.0 x 10^{2}
Se	6.3 x 10^{-3}	4.0 x 10^{-3}	1.5 x 10^{-2}	9.3 x 10^{0}	1.7 x 10^{2}
Si	8.8 x 10^{-2}	2.5 x 10^{-5}	4.0 x 10^{-5}	4.0 x 10^{-3}*	2.5 x 10^{0}
Sm	2.5 x 10^{-3}	2.0 x 10^{-5}	5.0 x 10^{-3}	5.0 x 10^{-1}*	3.0 x 10^{1}
Sn	7.5 x 10^{-3}	1.2 x 10^{-3}	8.0 x 10^{-2}	8.0 x 10^{0}*	3.0 x 10^{3}
Sr	6.3 x 10^{-1}	1.4 x 10^{-3}	8.1 x 10^{-4}	3.0 x 10^{-1}	1.0 x 10^{2}
Ta	2.5 x 10^{-3}	2.8 x 10^{-6}	6.0 x 10^{-4}	6.0 x 10^{-2}*	3.0 x 10^{4}
Tc	2.4 x 10^{0}	9.9 x 10^{-4}	8.5 x 10^{-3}	1.9 x 10^{0}	1.5 x 10^{1}

continued...

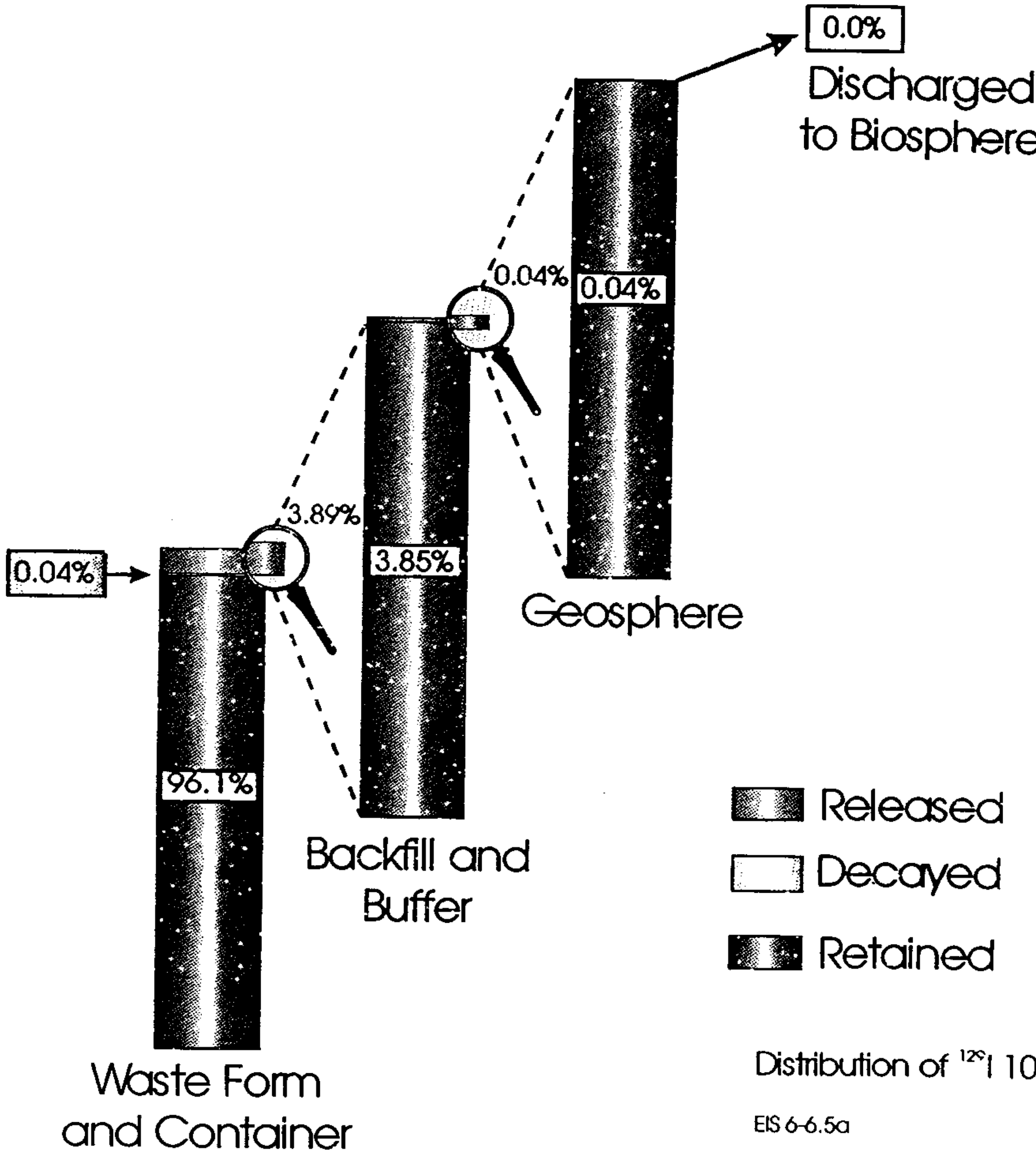
Issues Related to Waste Management

Unknowable setting

Burden to future generations

Long-lived, mobile, biologically active radionuclides

- I-129, Cl-36, C-14, Tc-99
- isotopic dilution



Distribution of ^{129}I 10^4 a

EIS 6-6.5a

Overview of International Programs

- Emphasis on the related biosphere
- High level and fuel
- Low and intermediate level

Country	Disposal design evaluated	Scope, methodology or other comments	References (Project name)
Belgium	1. HLW in inclined boreholes from tunnels in Boom clay, based on the Mol site 2. HLW emplaced in tunnels with TRU wastes in Boom clay, based on the Mol site	Concept assessment based on site data, deterministic and probabilistic analyses Concept assessment based on site data, deterministic and probabilistic analyses	Marivoet & Bonne 1988 (PAGIS) Niras/Ondraf 1989 (SAFIR)
Canada	UF in holes drilled from caverns in granite pluton based on the URL site at the Whiteshell Research Area	Assessment of a "Reference Disposal System", deterministic and probabilistic analyses	Goodwin, McConnell et al. 1994 (AECL EIS)
Denmark	HLW in boreholes drilled from the surface in a salt dome, based on in the Mors salt dome	Concept assessment based on limited site data, deterministic analyses	Lindstrøm Jenson 1987 (in support of PAGIS)
Germany	1. HLW in boreholes drilled from caverns in a salt dome, based on the Gorleben site 2. HLW in boreholes and UF emplaced horizontally in caverns in salt dome, at the Gorleben reference site	Concept assessment based on site data, deterministic and probabilistic analyses Inter-comparison of disposal concepts/options in salt to guide research	Storck et al. 1988 (PAGIS) Buhmann et al. 1991
France	HLW in granite inland massif (Auriat) and in low relief coastal site (Barfleur)	Concept assessment based on limited site data, deterministic and probabilistic analyses	Van Kote et al. 1988 (PAGIS)
Finland	UF in holes drilled from drifts in crystalline basement, based on data from five sites	Concept and geological guidance assessment based on site data, deterministic analyses	Vieno et al. 1992 (TVO 92)
Japan	HLW in crystalline and sedimentary formations with in-tunnel and deposition hole options considered	Generic concept assessments based on some site data, deterministic analyses	PNC 1992 (H3)
Netherlands	1. HLW in boreholes drilled from caverns in a salt dome 2. HLW in boreholes drilled from caverns in a salt dome	Concept assessment based on limited site data, deterministic analyses. Probabilistic safety assessment with special attention to methodology for scenario identification and treatment of uncertainties	Glasbergen et al 1987 (in support of PAGIS) Prij et al 1993 (PROSA)
Spain	HLW and UF in crystalline rock and salt formations	Preliminary engineering and safety concept studies.	ENRESA 1994

Table 5.1 Survey of published performance or safety assessments of geological disposal of nuclear fuel waste: vitrified high-level waste (HLW) or used fuel (UF) - part 1

Country	Disposal concept	Scope, methodology or other comments	References (Project name)
Sweden	1. HLW and UF in crystalline basement considering alternative concepts and progressively improving geological data 2. UF in crystalline basement following KBS-3 concept at hypothetical coastal site 3. UF in crystalline basement following KBS-3 concept, based on the Finnsjön site 4. UF in crystalline basement following KBS-3 concept, based on the Äspö site	1. Illustration of waste management options and preliminary concept safety assessments 2. Demonstration of PA methodology, deterministic analysis 3. Concept and geological guidance assessment using real site data, deterministic and probabilistic analyses 4. Development of aspects of methodology for assessment using real site data	KBS 1977,1978,1983 (KBS-1, 2, 3) SKI 1991 (Project 90) SKB 1992 (SKB 91) SKI in preparation (SITE 94)
Switzerland	1. HLW in crystalline basement in N. Switzerland 2. HLW in sedimentary rocks in N. Switzerland. 3. HLW in crystalline basement in N. Switzerland.	Engineering and safety feasibility study, deterministic analysis Concept assessment, deterministic analysis Safety assessment and geological siting study, deterministic analysis	Nagra 1985 (Project Gewähr) Nagra 1988 Nagra 1994 (Kristallin-I)
United Kingdom	1. HLW in crystalline rocks, above and below water table, and in clay 2. HLW in clay layer, based on Harwell site	Preliminary concept assessments, simple deterministic evaluation of alternatives. Concept assessment based on site data, deterministic and probabilistic analyses	Burton & Griffin, 1981 Marivoet & Bonne 1988 (PAGIS)
United States	Various, notably: 1. UF in basalt flows based on the Hanford site 2/3. UF in dry deposition holes in unsaturated welded tuff at the Yucca Mountain site	1. Environmental assessment prior to detailed site investigation, for regulatory approval 2. Demonstration of assessment methodology with most recent site data prior to tunnel construction. 3. Setting priorities for site characterisation, guide repository design and develop methodology	US DOE 1986 Barnard et al 1992 (TSPA 1991) Wilson et al 1994 (TSPA 1993)

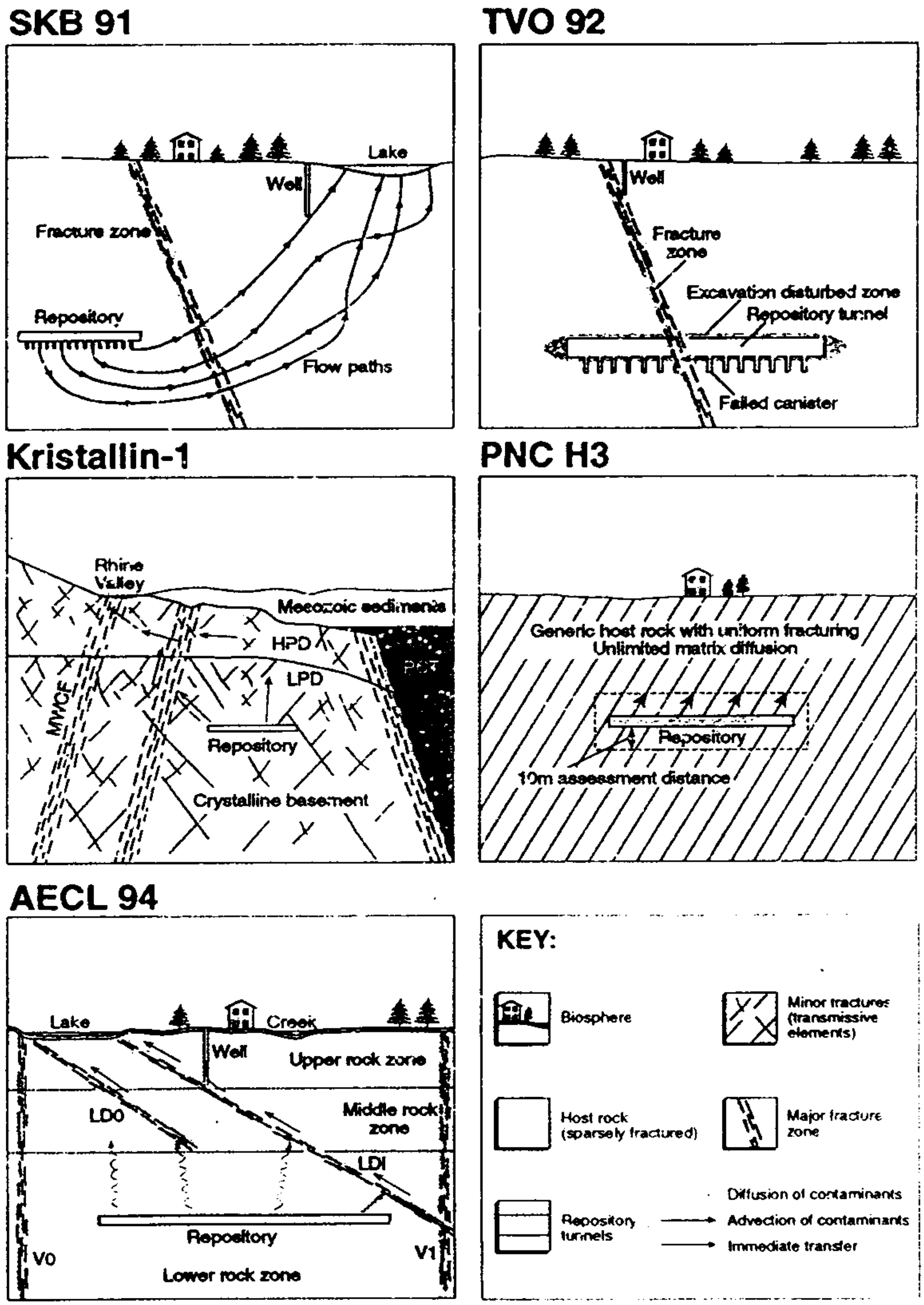
Table 5.1 Survey of published performance or safety assessments of geological disposal of nuclear fuel waste: vitrified high-level waste (HLW) or used fuel (UF) - part 2

	SKB 91	TVO 92	Kristallin-1	PNC H3	AECL 94
Resaturation of vault	Assumed instantaneous	Assumed instantaneous	Assumed instantaneous	Assumed instantaneous	Assumed instantaneous
Container failure	Probability of initial defect	Disappears at 10 000 y	Disappears at 1000 y	Disappears at 1000 y	Several failure modes modelled; all fail by 10 000y
Contaminant release from the waste	Instant release component plus slower matrix degradation	Instant release component plus slower matrix degradation	Matrix degradation only	Matrix degradation only	Instant release component plus slower matrix dissolution
Solubility limitation	Yes	Yes	Yes	Yes	Yes
Contaminant transport in buffer	Diffusion to host rock and EDZ	Diffusion to EDZ	Diffusion to EDZ	Diffusion to outer boundary	Diffusion upwards to backfill
Contaminant transport in backfill	Conservatively neglected	Conservatively neglected	Not applicable	Not applicable	Diffusion upwards to geosphere
Transport from repository	Spatially distributed source to geosphere	Instantaneously along EDZ to fracture zone	Instantaneously along EDZ to water-conducting features in rock	Instantaneously to geosphere transport path	Vault sectors connected to geosphere transport paths
Transport in sparsely fractured host rock	Advection in dual-porosity stream tubes in variable hydraulic conductivity field	Conservatively not included in transport path	Advection in channels within water-conducting features	Advection in fractured or continuos porous medium	Advection and diffusion in equivalent porous medium (diff-usion dominates)
Transport in major fracture zones	Fracture zones are included as trend functions with higher median conductivity than the sparsely fractured rock mass	Advection in a dual-porosity medium	Instantaneous (included in an alternative model)	Not considered (Release calculated at 10, 100 and 1000 m from vault)	Advection and diffusion in equivalent porous medium (advection dominates)
Transport in overlying geo-units	None	None	Rapid	Not considered	Advection and diffusion in sediment cover
Surface environment (biosphere)	Well, lake and agricultural pathways	Well, lake and agricultural pathways	Gravel aquifer, well, river and agricultural pathways	Not defined. Drinking water dose applied to geosphere flux	Well, lake, agricultural and other pathways
Critical Group	Subsistence farmers	Subsistence farmers	Subsistence farmers	Individual drinking water	Subsistence farmers and hunters.*

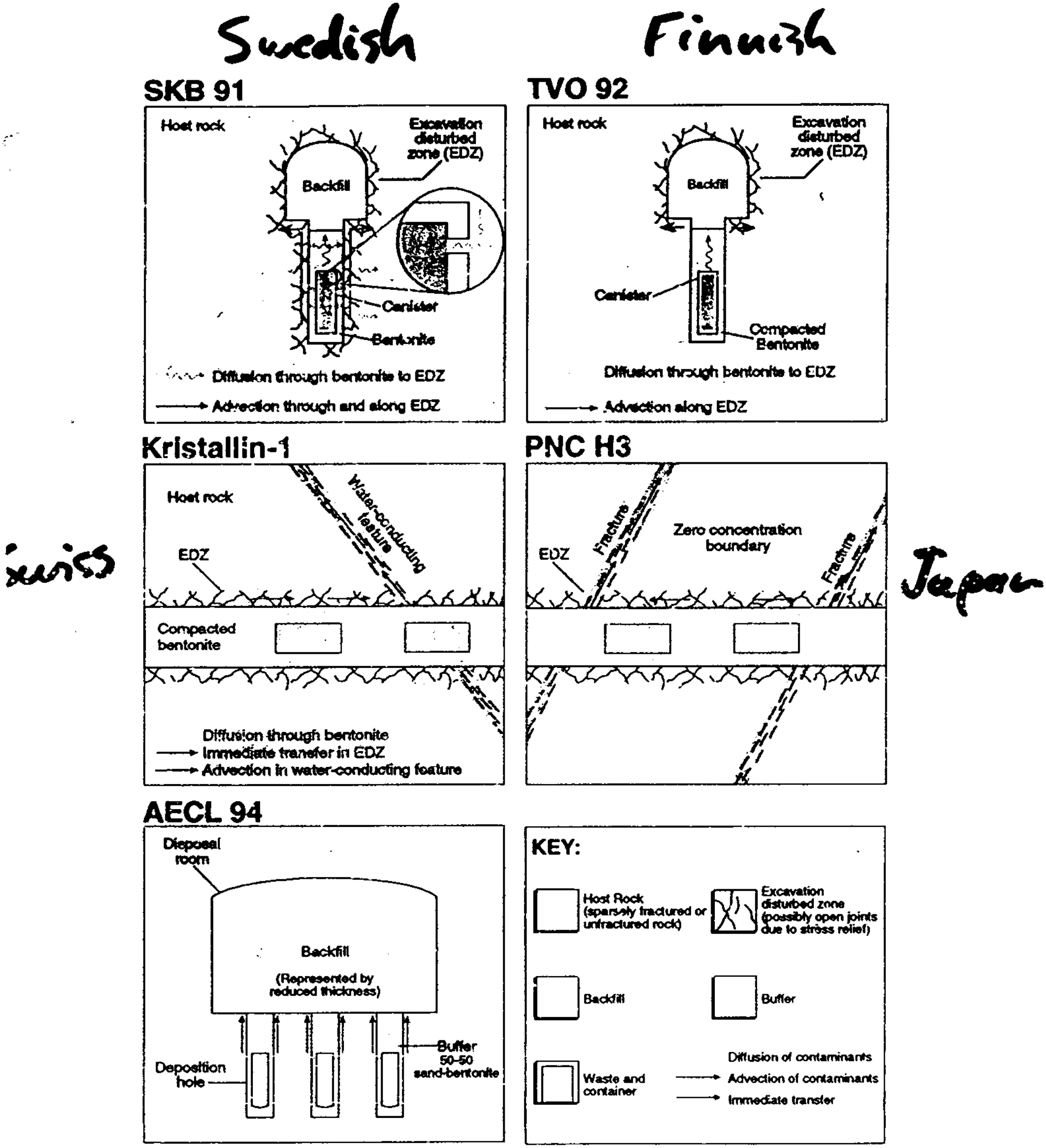
Refer also to Figures 7.1 and 7.2

* Doses to other biota also calculated.

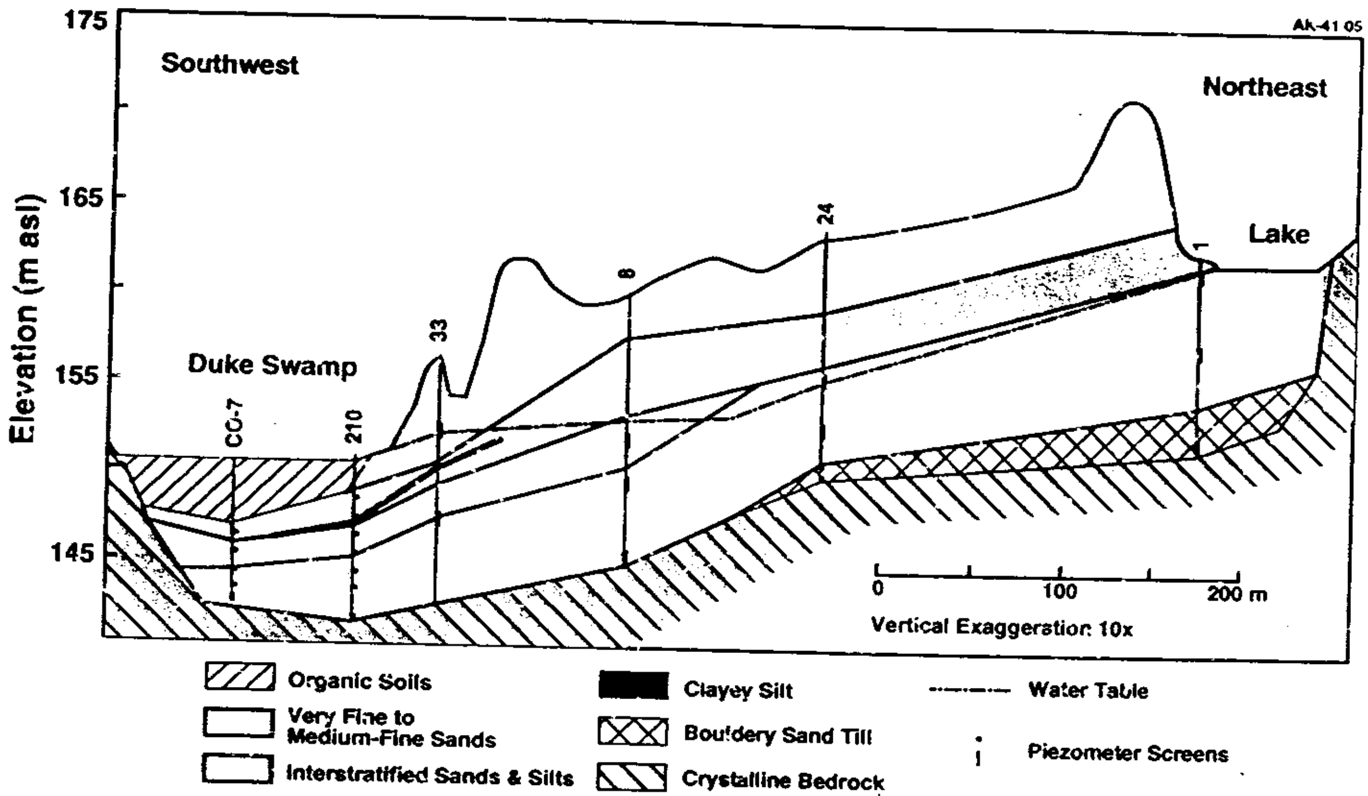
Table 7.1 Primary conceptual model choices - comparison of the main features, processes and assumptions contained in the assessment model chains of groundwater-mediated release for each of the five assessments



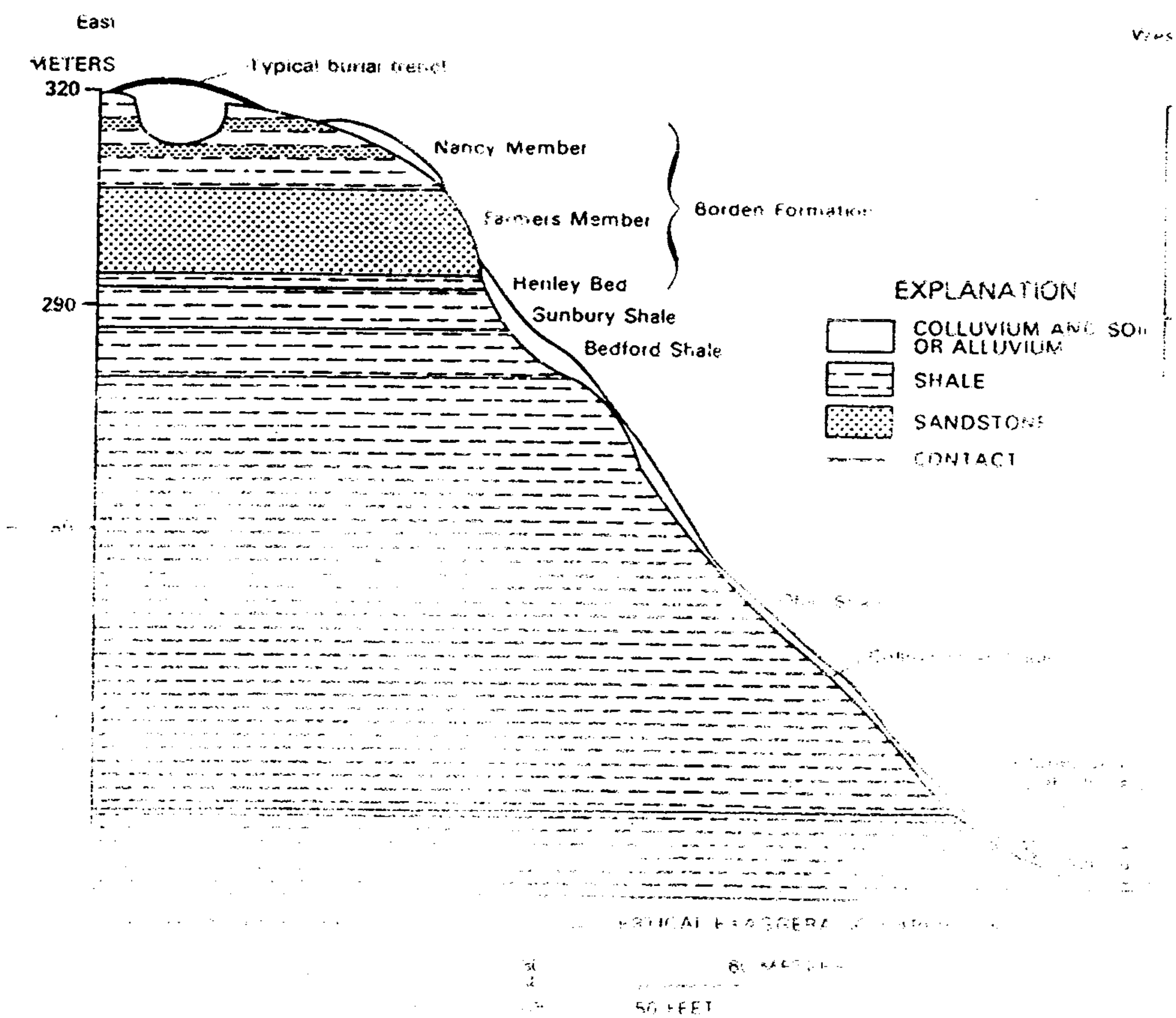
See also Tables 7.1 and 7.4.



See also Tables 7.1 and 7.3.



Ak-41 05
Southwest
Northeast
Elevation (m asl)
175
165
155
145
Duke Swamp
Lake
CO-7
210
33
8
24
1
0
100
200 m
Vertical Exaggeration 10x
Organic Soils
Very Fine to Medium-Fine Sands
Interstratified Sands & Silts
Clayey Silt
Bouldery Sand Till
Crystalline Bedrock
Water Table
Piezometer Screens


East
METERS
320
290
Typical burial trench
Nancy Member
Farmers Member
Borden Formation
Henley Bed
Sunbury Shale
Bedford Shale
EXPLANATION
COLLUVIUM AND SOIL OR ALLUVIUM
SHALE
CONTACT
50 FEET

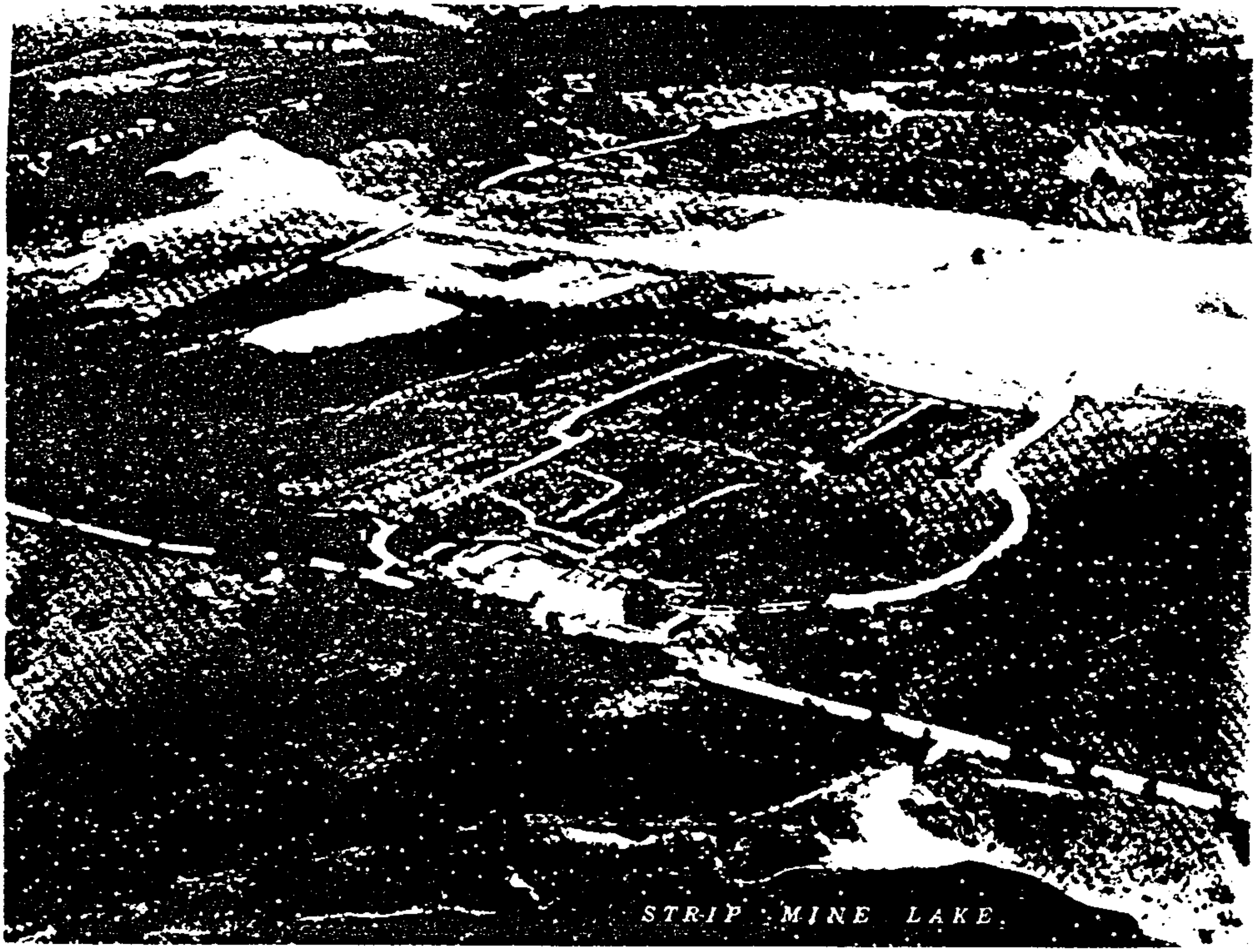

STRIP MINE LAKE

Table Ib. Risk related criteria:

Criteria as listed in the review	Specific to:	Met by Canadian concepts
remote location with sparse population		yes
intrusion barrier, especially to non-human biota, because of groundwater		some
low possibility for human intrusion because of subsea location	subsea	none
in communities that received most benefit from nuclear industry		some
in stable rock formations where intrusion is unlikely	deep	some
more than 1 km to streams, no springs or other discharges on site		none
no exploitable resources		some
future population growth and developments not likely to affect the performance		some
the waste should be below the rooting zone of indigenous plants		some
avoid critical habitats of endangered species or special cultural resources		yes
no irrigated or irrigable land		none
no surficial sand or gravel deposits		some
far from surface water supplies		none
little prime agricultural land		some
exclude protected lands, including deer wintering areas		—
avoid Class 1 agricultural lands		yes
large enough site so vaults are 1000 m from the site border		some
not above an aquifer that serves a community or a business	surface	yes
seek areas with low projected population growth		yes
more than 15 miles (~24 km) of a community of 100,000		yes
more than two miles (~3 km) of a community of 5000		—
avoid quarry blasting, conflicting sources of radiation and military lands		yes
more than 2 km from boundary of population centers		yes
avoid the wind corridor, upwind or downwind, of existing facilities		none
avoid bogs or wetlands at the groundwater discharge point which may accumulate radionuclides		some
avoid areas with fair or good forestry potential		some
avoid good recreational potential (in the case that institutional control fails)		none
have road access avoiding residential streets		yes
significant natural areas, such as areas with species that are		yes

1. Glacial sediments.

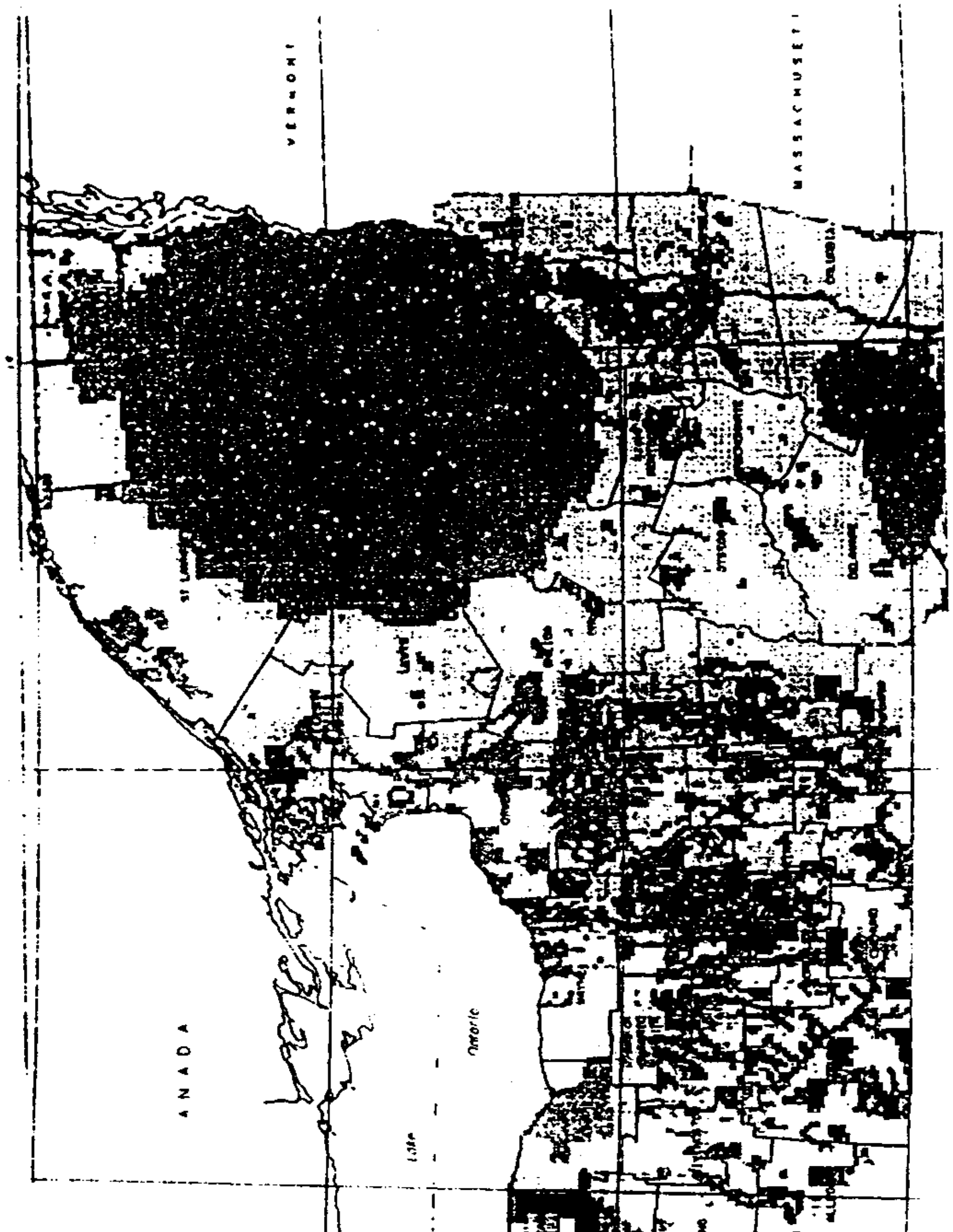
2. Great Lakes ten-mile exclusion zone.

3. Vegetative cover surrogate for wetlands.

4. Major surface water bodies.

5. Remaining area after exclusionary screen.

Fig 70



Discharge to the Biosphere

- Groundwater discharge
  - low lying areas
  - methods to detect
  - characteristics
- Water wells
- Gaseous discharges

Methods to detect groundwater discharge

- ping pong balls
- deer
- salinity probe

Salinity probe

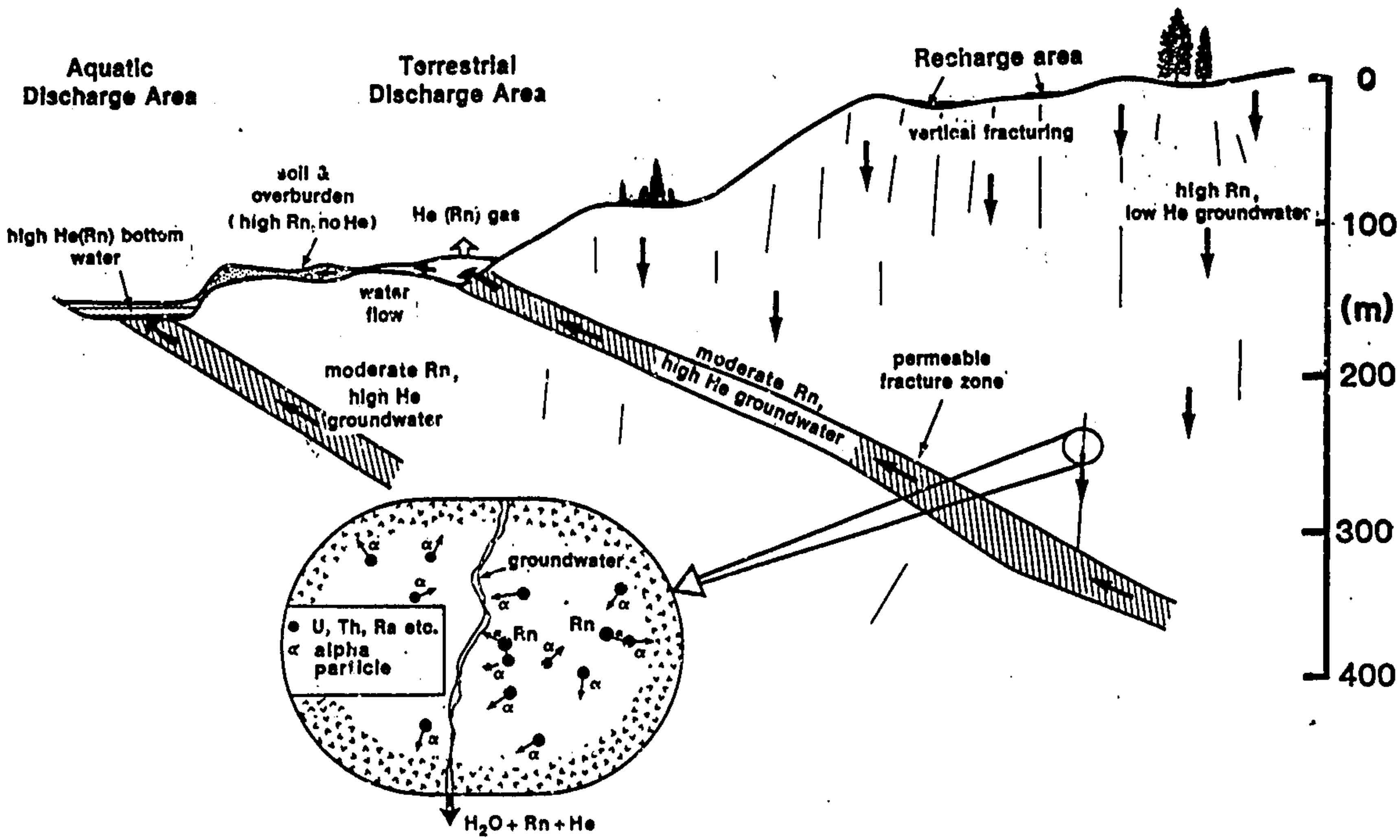
- drag along lake and river bottoms
- detects variation in temperature, salinity
- expect greater salinity for a discharge of deep groundwater
- not a positive test, e.g. will detect evaporite

Animal behavior

- animal licks
  - associated with mineralization
  - often sodium and chloride
  - not a positive test

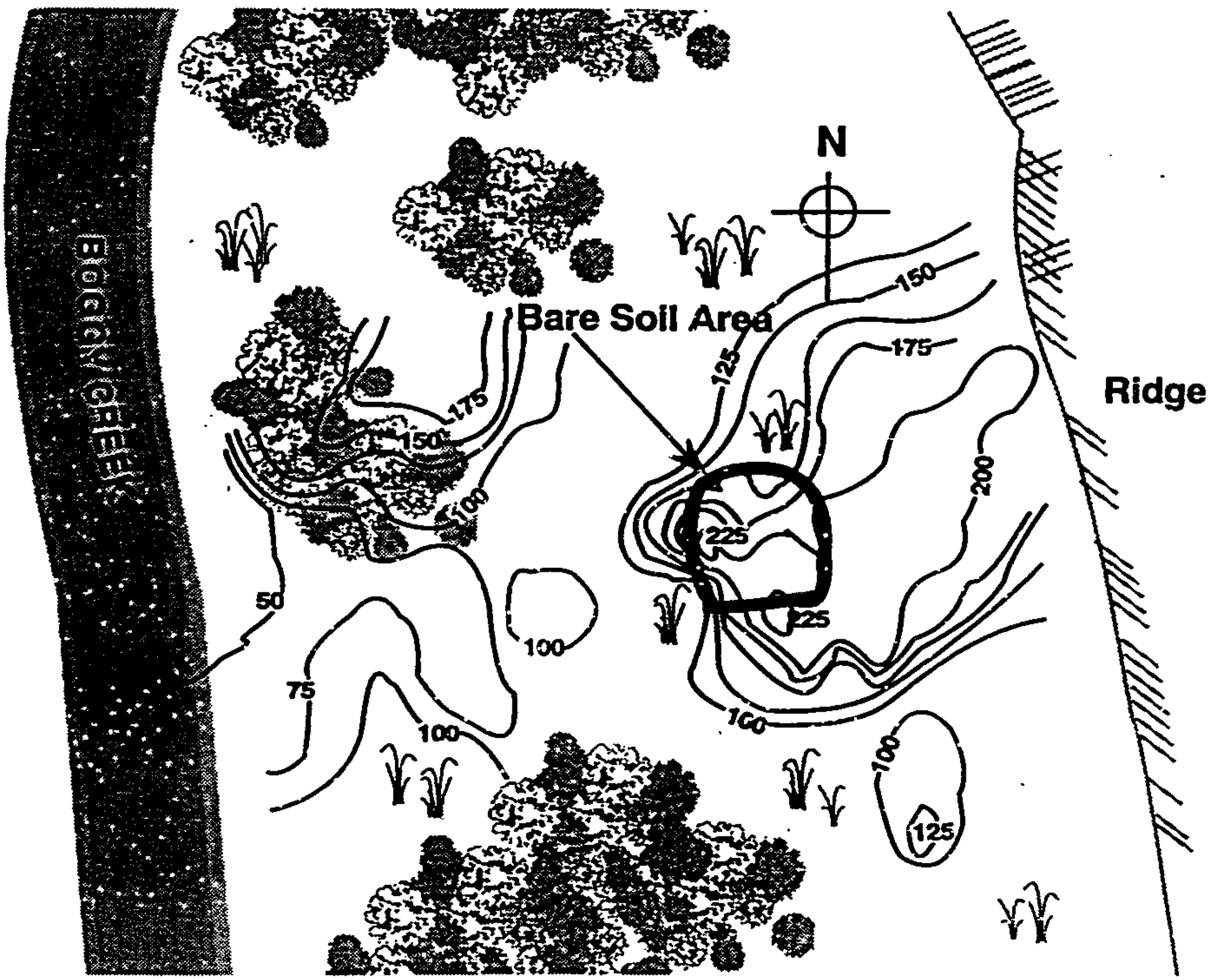
Helium (He) discharge

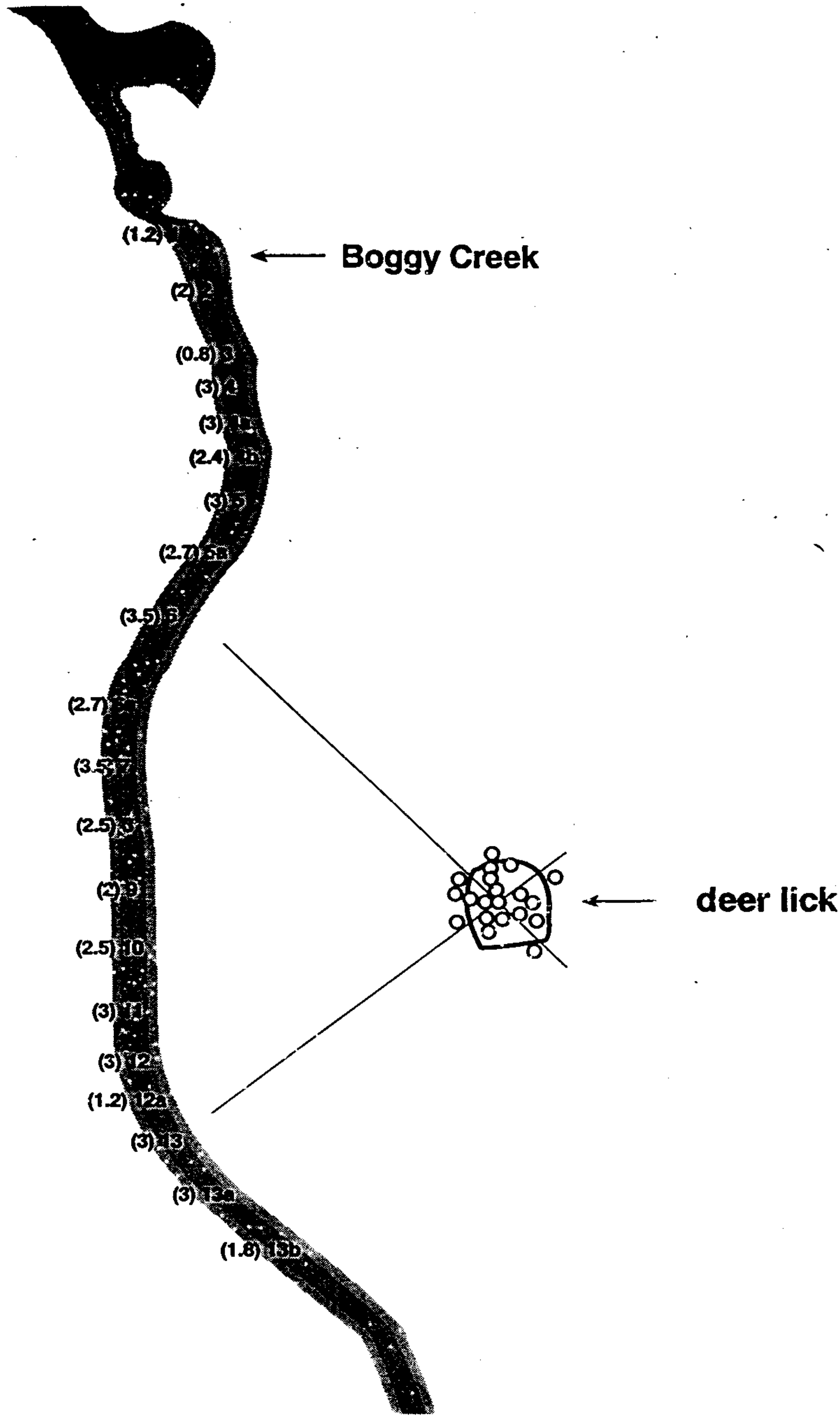
- alpha decay creates helium nucleus
- helium moves with water or as a gas
- easily detected, low concentration in the atmosphere
- a helium signature indicates:
  - uranium mineralization near surface;
  - concentrated discharge of a large volume of rock

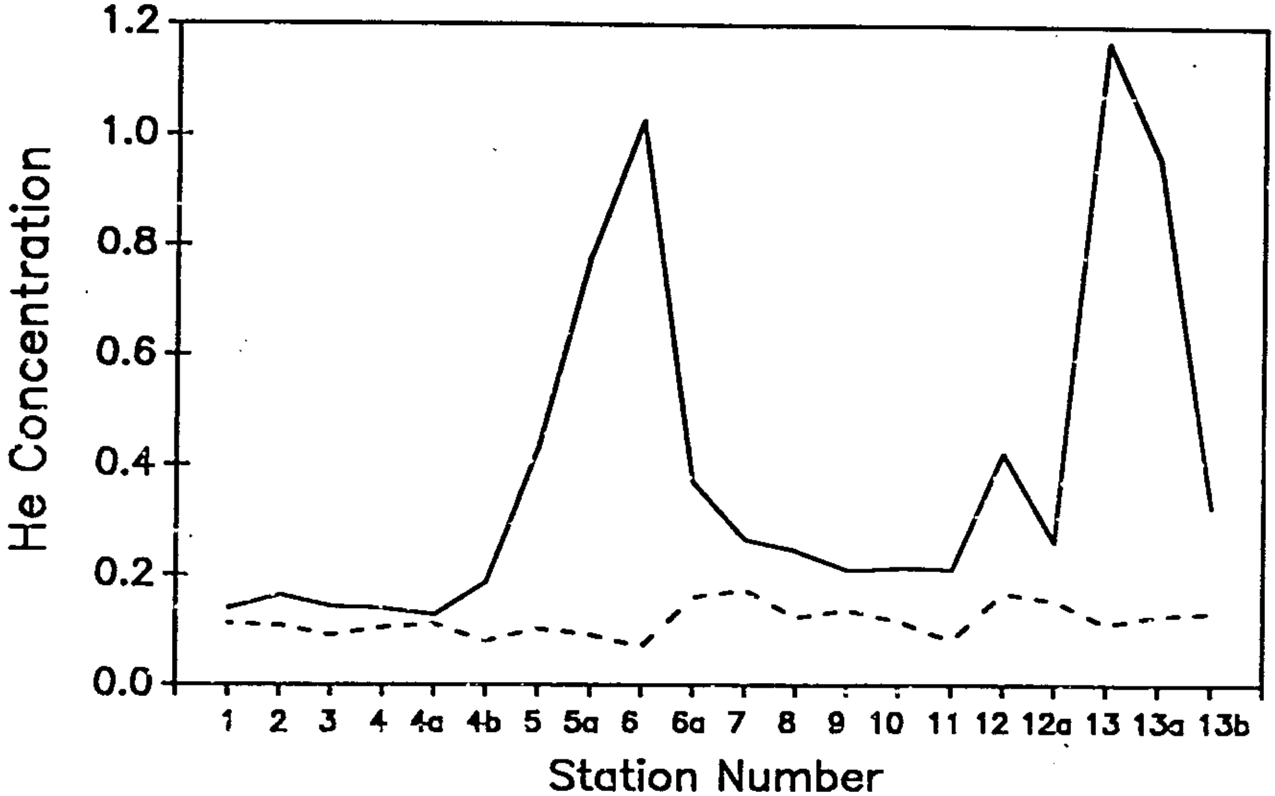


Aquatic Discharge Area
Terrestrial Discharge Area
Recharge area
vertical fracturing
high Rn, low He groundwater
soil & overburden (high Rn, no He)
He (Rn) gas
high He(Rn) bottom water
water flow
moderate Rn, high He groundwater
moderate Rn, high He groundwater
permeable fracture zone
0
100
(m)
200
300
400
groundwater
U, Th, Ra etc.
α alpha particle
Rn
Rn
$H_2O + Rn + He$

EC (mS/m)




Boggy Creek
deer lick
(1.2)
(2)
(0.8)
(3)
(3)
(2.4)
(3)
(2.7)
(3.5)
(2.7)
(3.5)
(2.5)
(2)
(2.5) 10
(3)
(3) 12
(1.2) 12a
(3) 13
(3)
(1.8)


He Concentration
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1 2 3 4 4a 4b 5 5a 6 6a 7 8 9 10 11 12 12a 13 13a 13b
Station Number