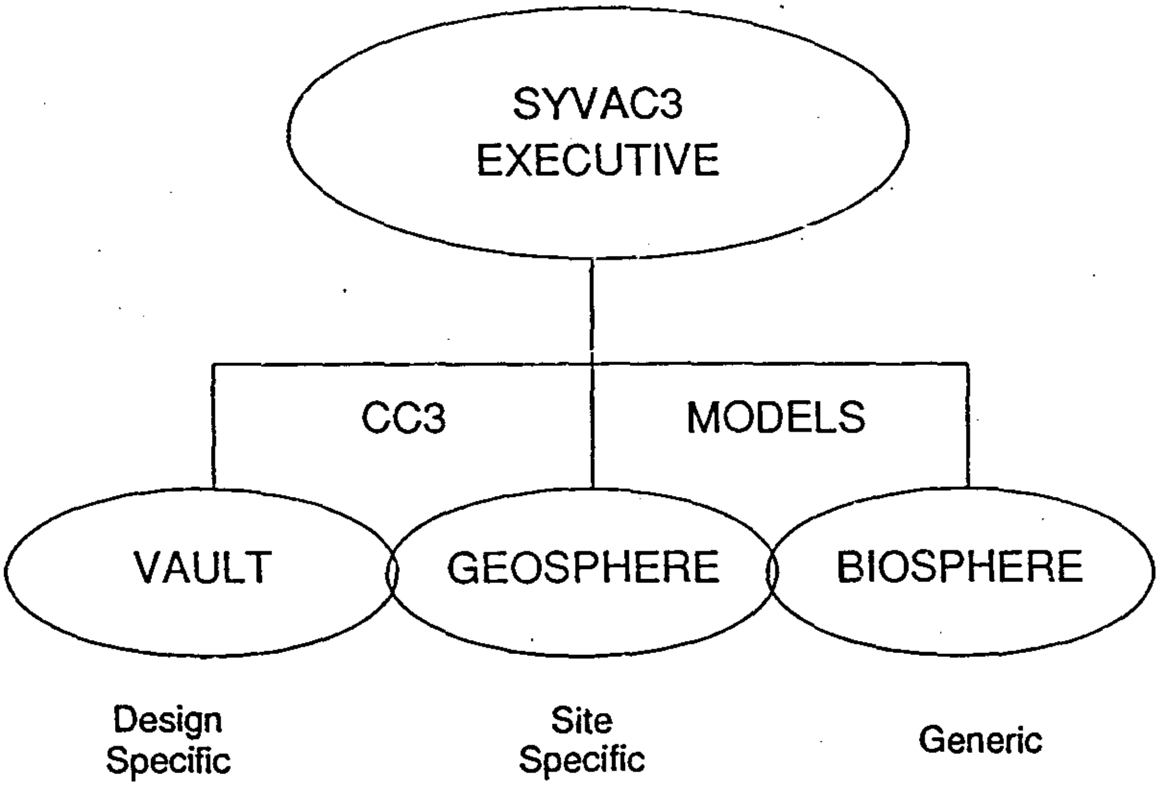
Section 5

Canadian System Model

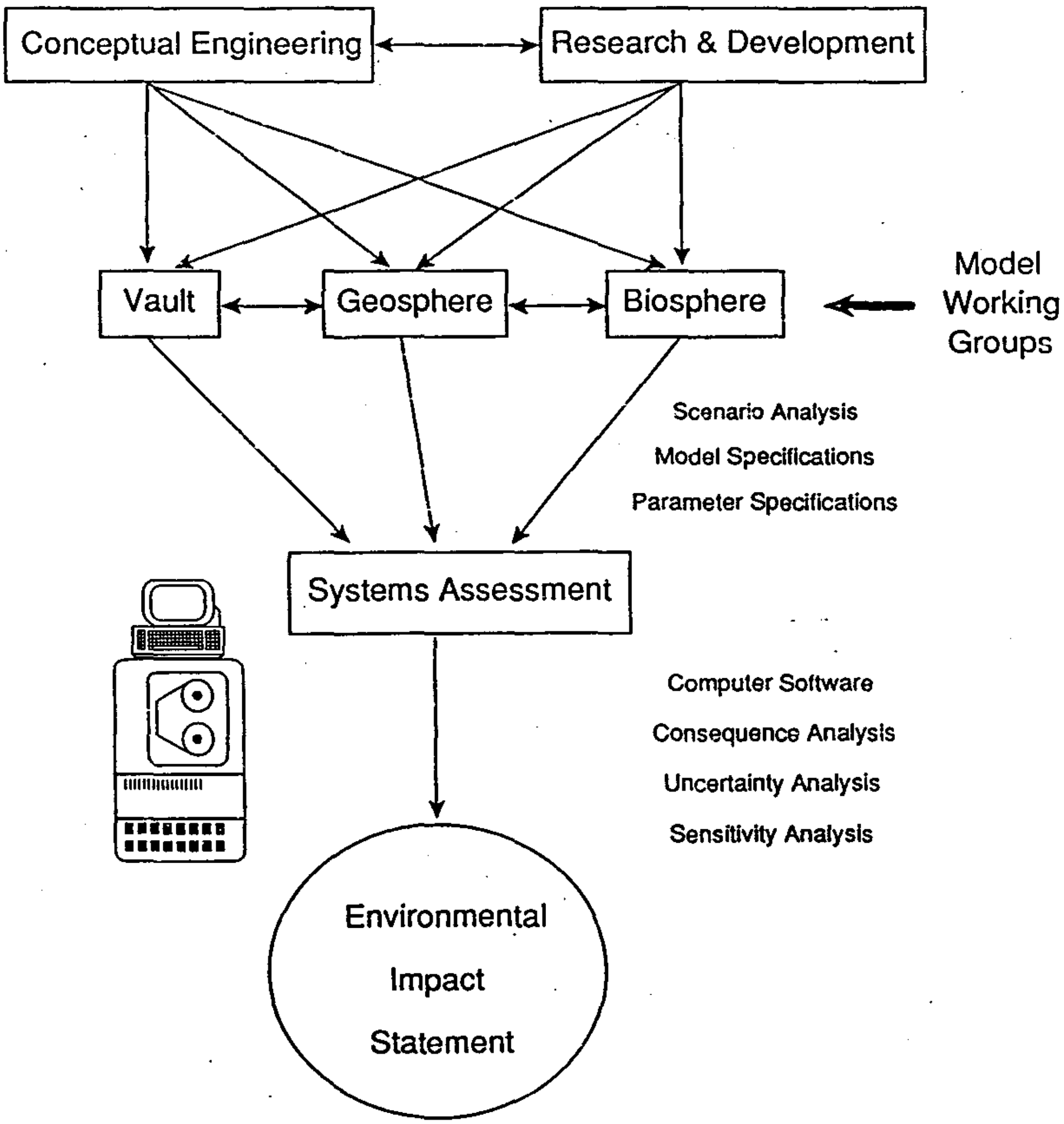
and

SYVAC3-CC3
display package

SYVAC3-CC3 SYSTEM ASSESSMENT CODE



PROGRAM LINKAGES



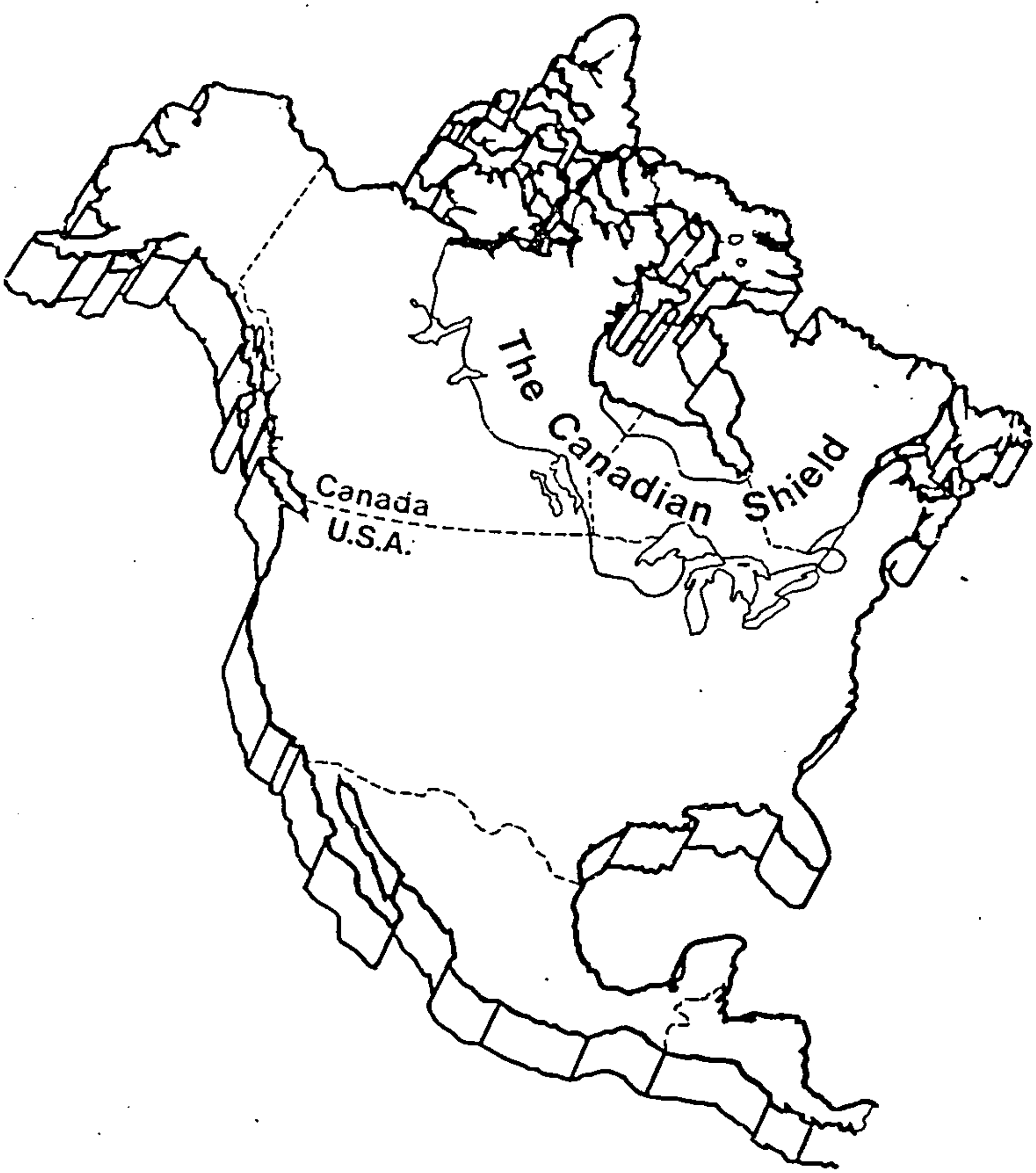
CC3

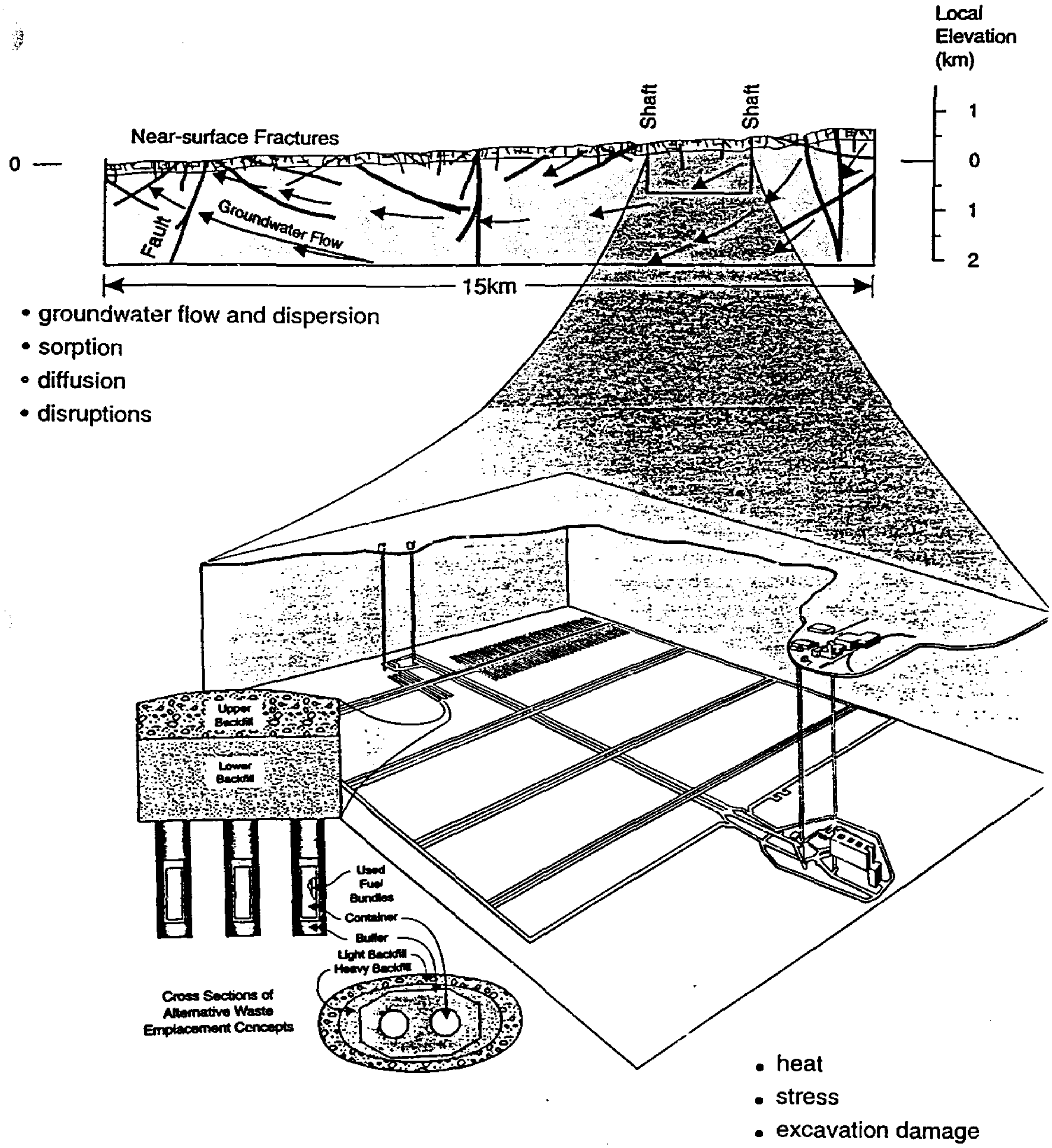
VAULT

MODEL

PERFORMANCE ASSESSMENT WORKSHOP

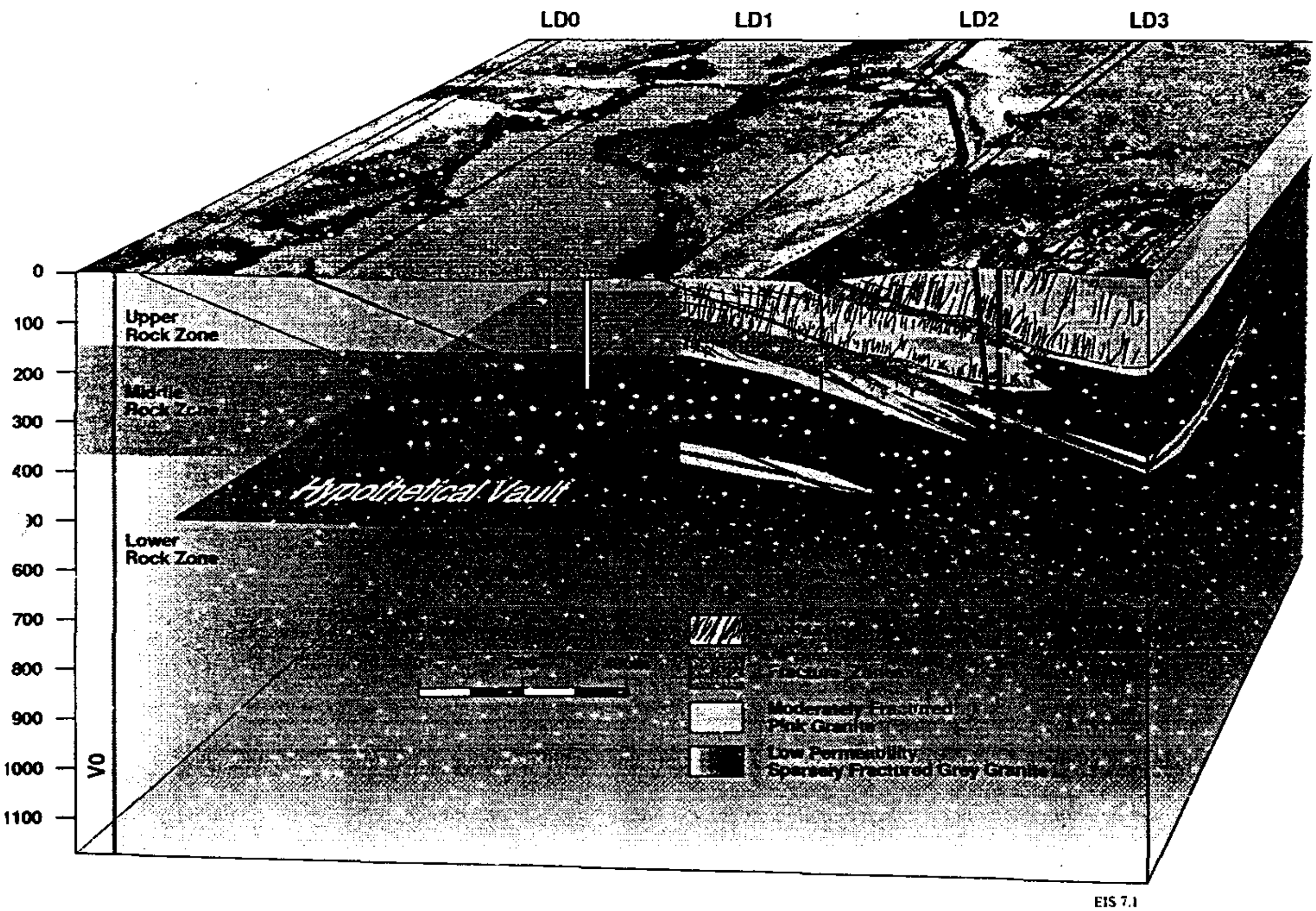
SECTION 1	INTRODUCTION	FIGURE 1




Local
Elevation
(km)
Shaft
Shaft
Near-surface Fractures
0
1
0
1
2
Fault
Groundwater Flow
15km
• groundwater flow and dispersion
• sorption
• diffusion
• disruptions
Upper Backfill
Lower Backfill
Used Fuel Bundles
Container
Buffer
Light Backfill
Heavy Backfill
Cross Sections of Alternative Waste Emplacement Concepts
• heat
• stress
• excavation damage

Location of Hypothetical Disposal Vault in Geosphere

(500 m depth, site conditions similar to URL/WRA)

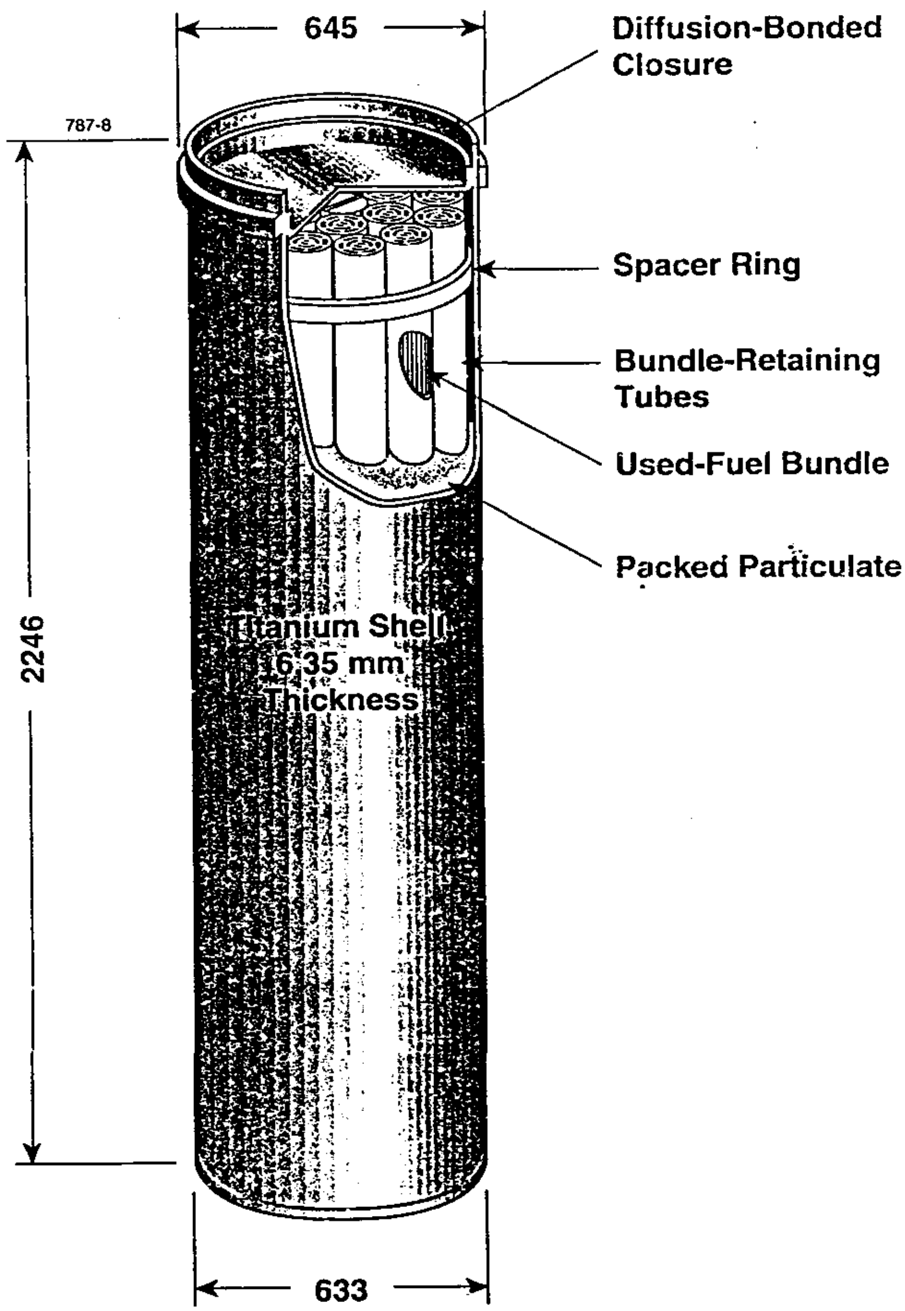


Components of Vault Model

1. **Container failure**
2. **Source terms**
3. **Mass transport**
4. **Exit boundary condition**

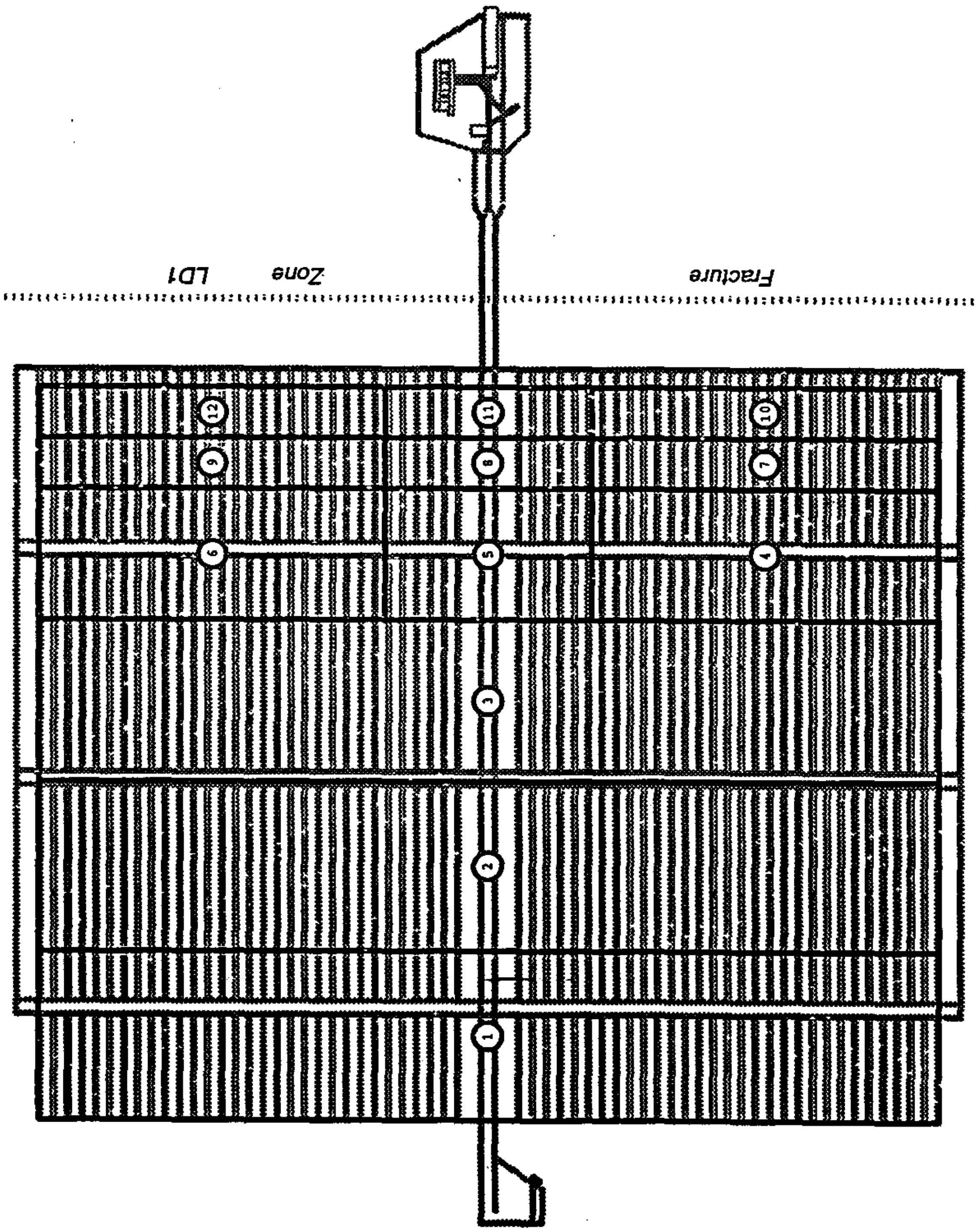
PERFORMANCE ASSESSMENT WORKSHOP

SECTION 9	VAULT	FIGURE 5



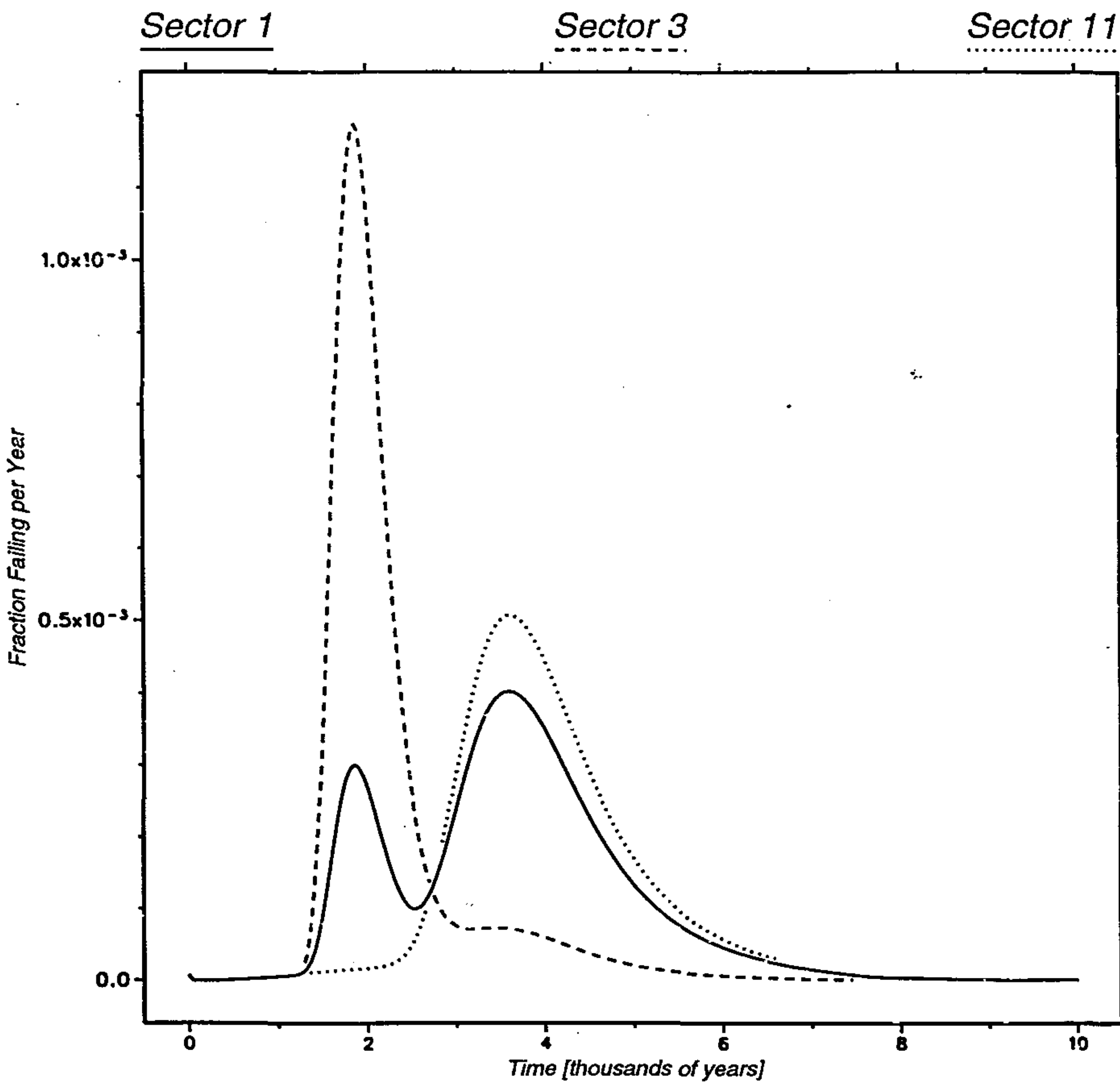
Packed-Particulate Fuel Isolation Container

PERFORMANCE ASSESSMENT WORKSHOP		
SECTION 9	VAULT	FIGURE 3

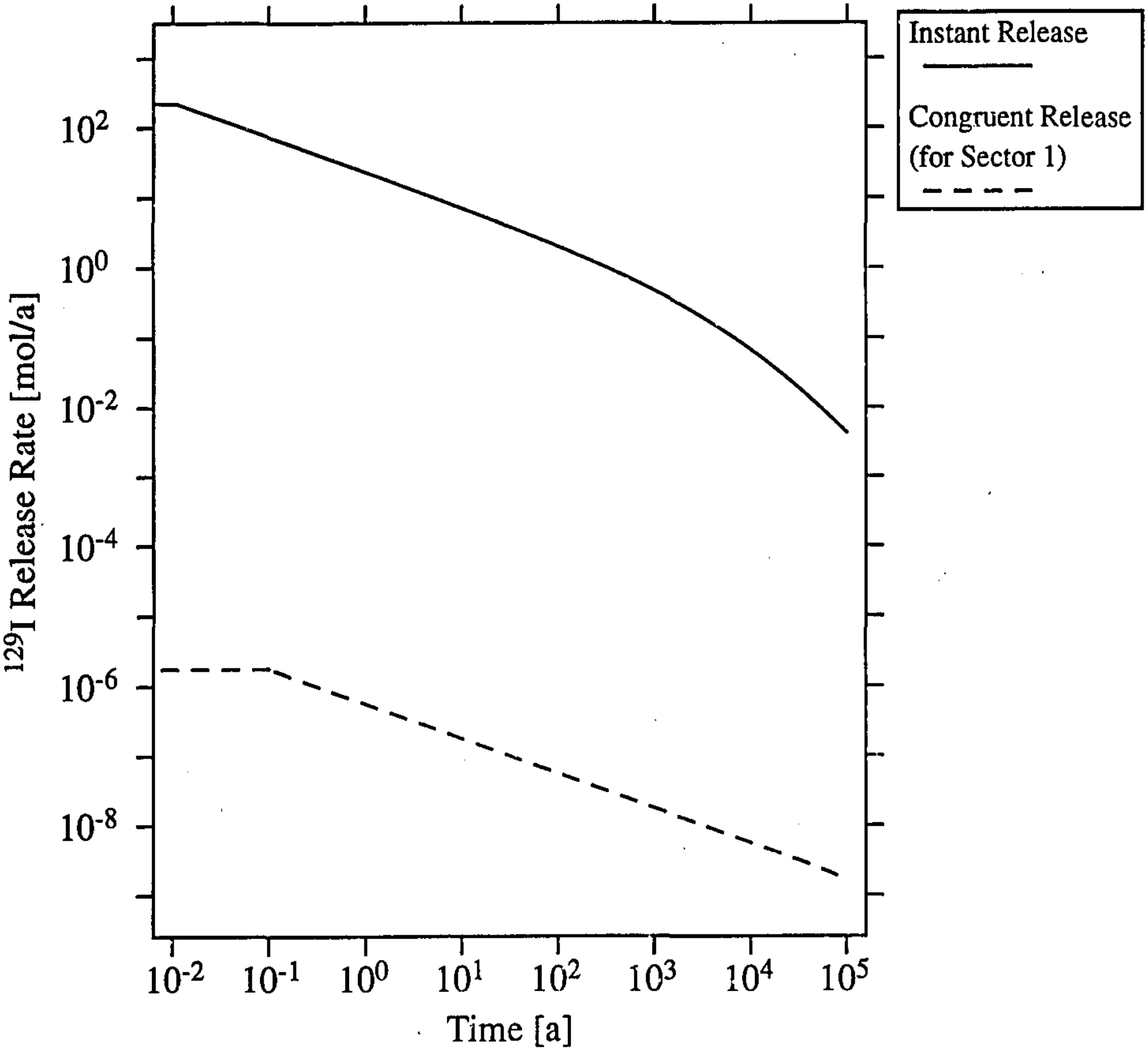


PERFORMANCE ASSESSMENT WORKSHOP

SECTION 9	VAULT	FIGURE 9



Release Rate from Wasteform



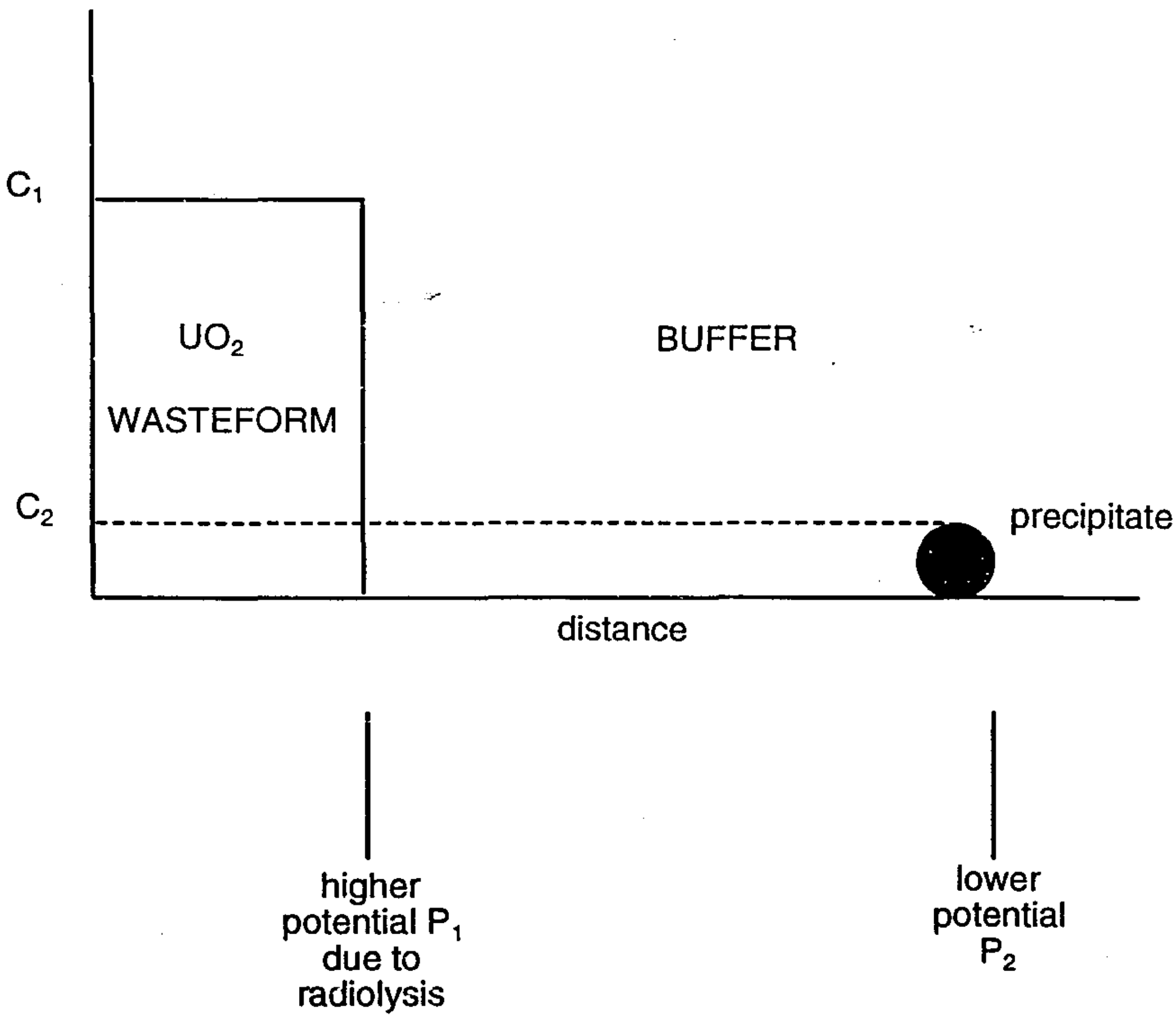
PERFORMANCE ASSESSMENT WORKSHOP

SECTION 9

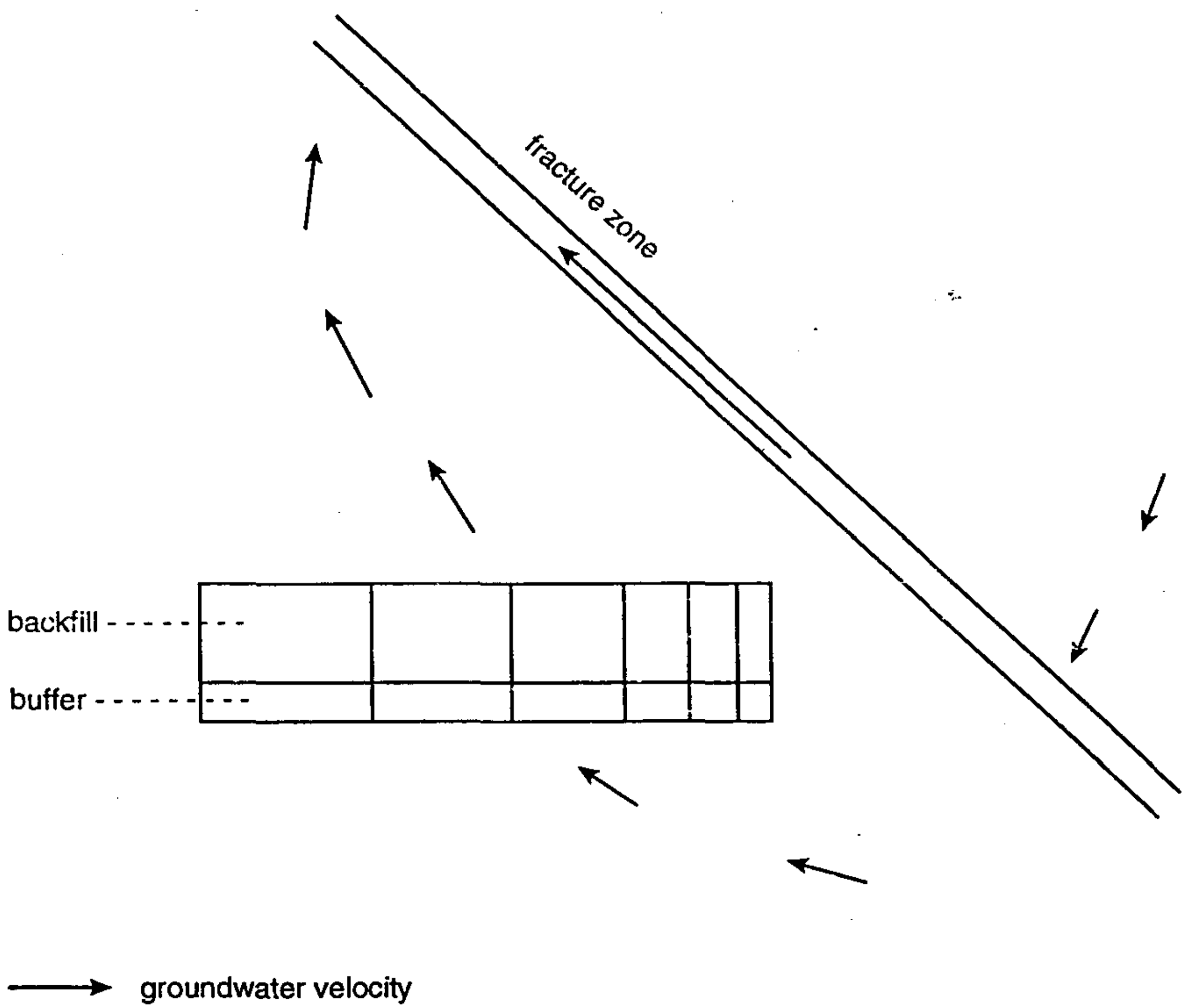
VAULT

FIGURE 14

92-119

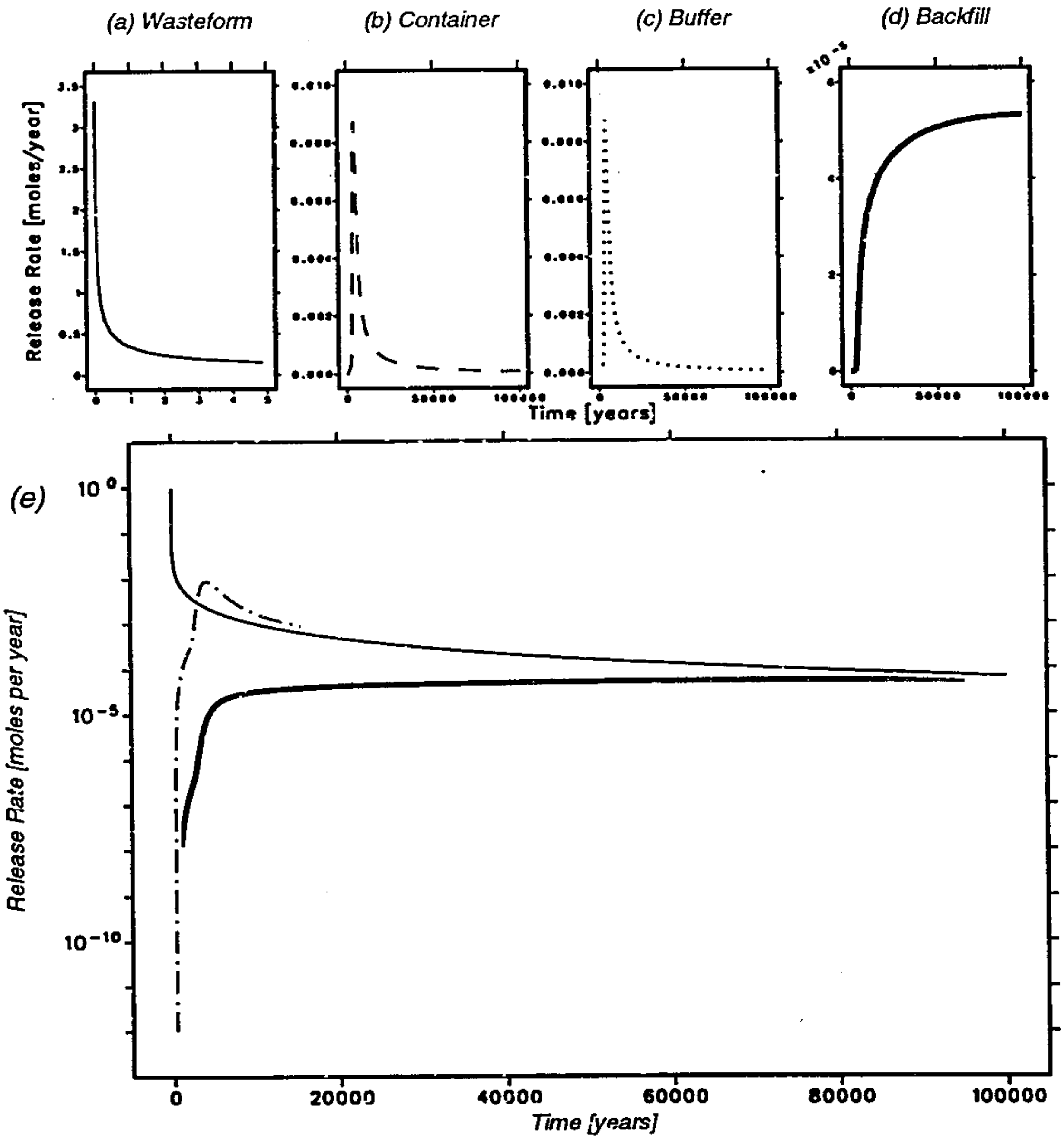

C1
C2
UO2
WASTEFORM
BUFFER
precipitate
distance
higher
potential P1
due to
radiolysis
lower
potential
P2

SECTORS REPRESENTED AS ONE OR TWO LAYERED SLABS - END EFFECTS ARE NEGLECTED



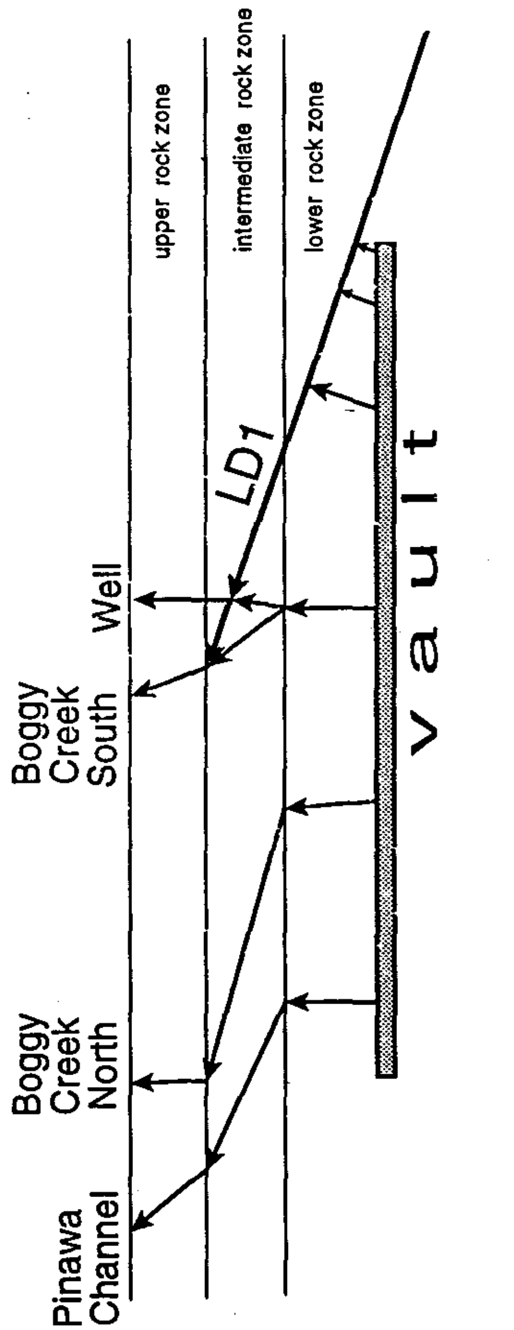
PERFORMANCE ASSESSMENT WORKSHOP

SECTION 9 | **VAULT** | **FIGURE 20**



PERFORMANCE ASSESSMENT WORKSHOP

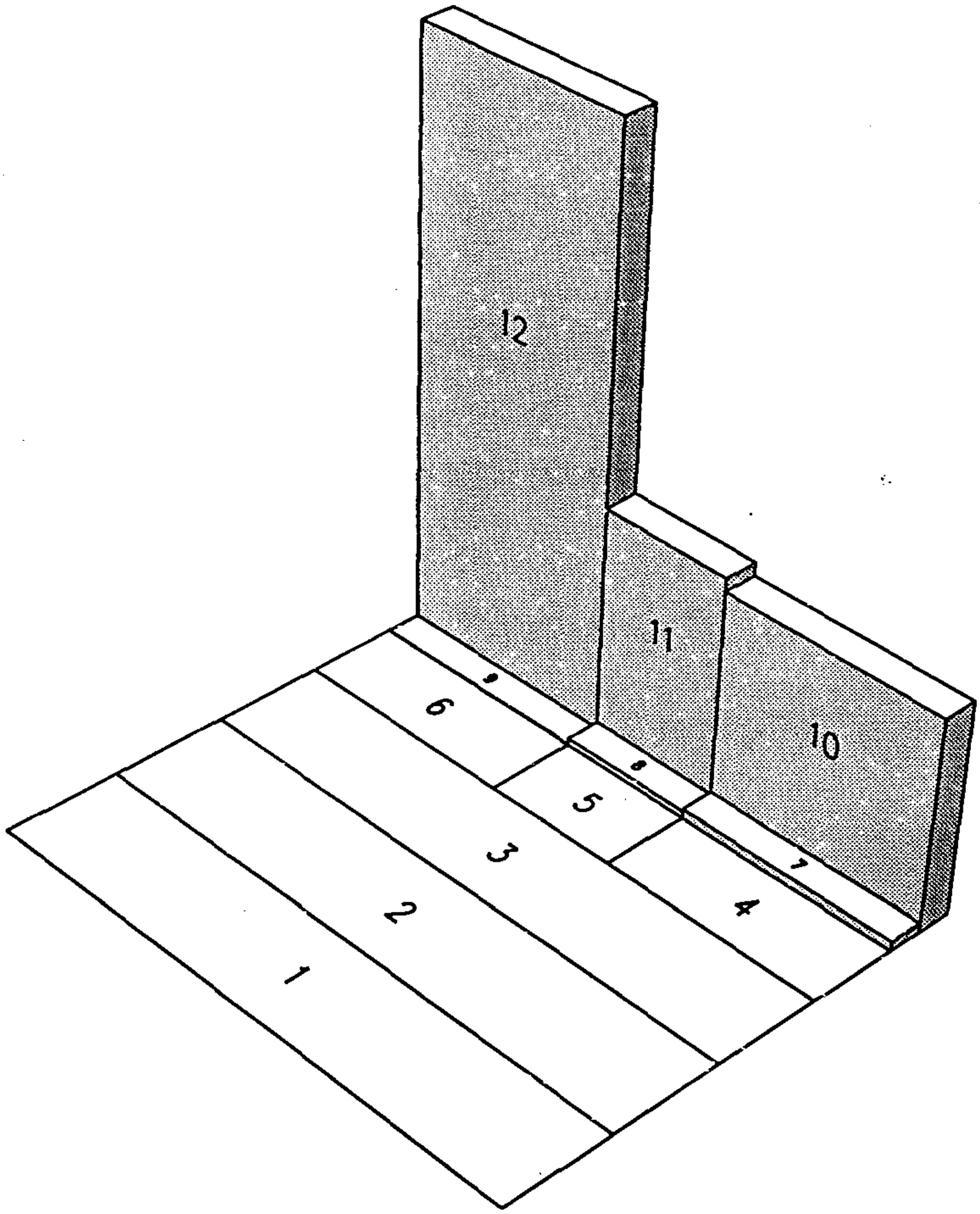
SECTION 9	VAULT	FIGURE 2



Cross-section with projection of transport network

PERFORMANCE ASSESSMENT WORKSHOP

SECTION 9 | **VAULT** | **FIGURE 22**



CC3

GEOSPHERE

MODEL

CC3 GEOSPHERE SUBMODEL PHILOSOPHY

MATCH AS CLOSELY AS FEASIBLE

DETAILED FIELD INFORMATION
DETAILED HYDROLOGICAL MODELLING

OF A REAL SITE INCLUDING

GEOLOGICAL STRUCTURE
GEOCHEMISTRY
HYDROLOGY

WITH A HYPOTHETICAL VAULT
AT 500 m DEPTH

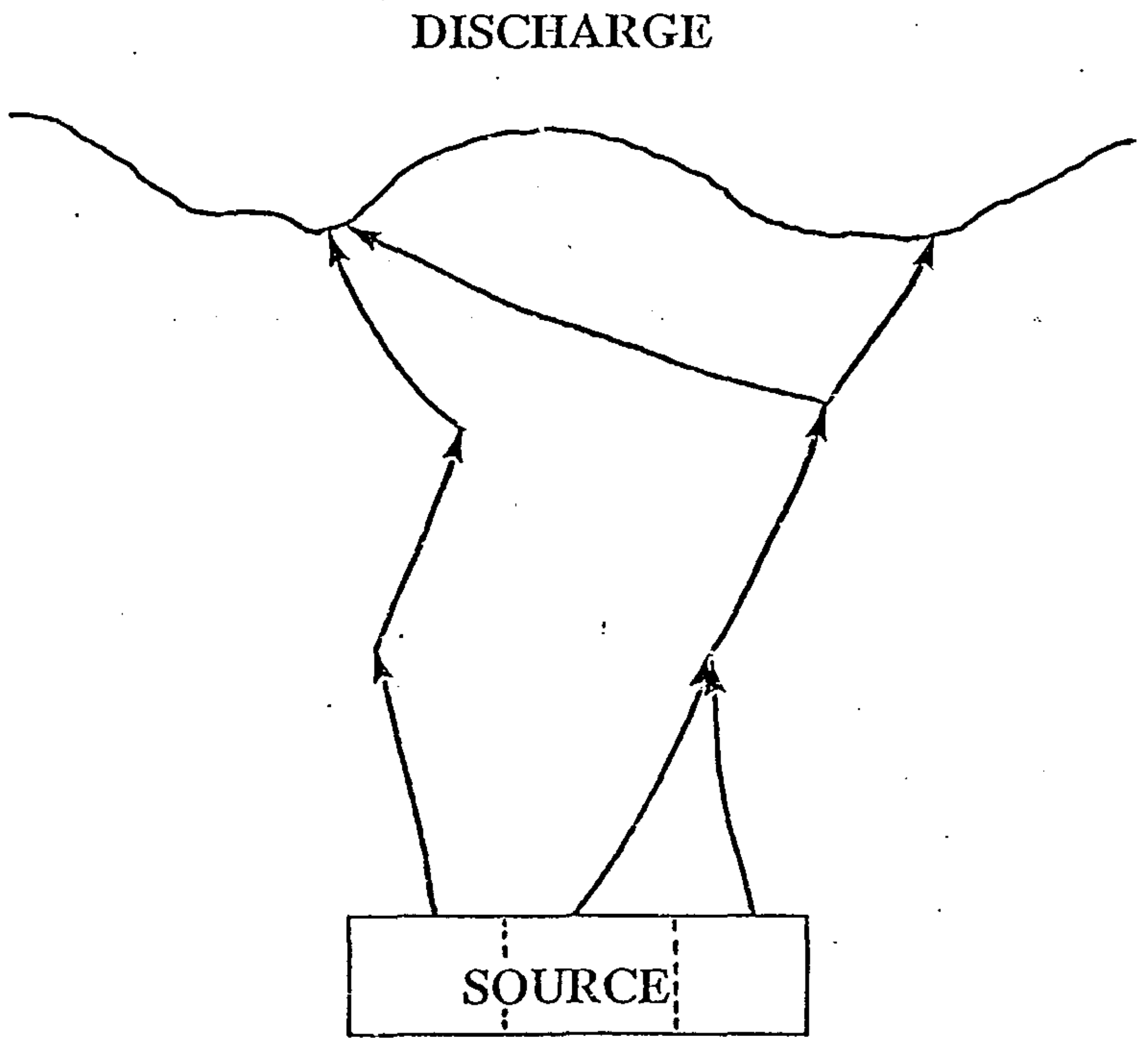
SUBMODEL CONCEPT

1 MIMIC 3-D GEOSPHERE DATA BY
NETWORK OF
1-D SEGMENTS

CONSTANT PROPERTIES IN SEGMENTS
SEGMENTS CONNECTED INTO PATHS
PATHS COMBINED INTO DISCHARGES
PATHS CAN CONVERGE AND DIVERGE

2 MATCH NETWORK TO DETAILED
HYDROLOGICAL MODELLING BY
COMPARISONS OF CALCULATED
RESULTS FOR NONSORBING
NONDECAYING WATER TRACER

3 WHEN MATCH IS ADEQUATE FIX
NETWORK FOR COMPLETE
ASSESSMENT WITH RADIONUCLIDE
CHAINS



NETWORK SCHEMATIC

MATHEMATICAL MODEL FOR A SEGMENT

SEGMENT OUTPUT OBTAINED BY CONVOLUTION OF RESPONSE FUNCTION WITH SEGMENT INPUT

RESPONSE/GREENS FUNCTION IS SOLUTION TO CONVECTION - DISPERSION - DECAY - RETARDATION MASS BALANCE DIFFERENTIAL EQUATION

RESPONSE FUNCTION DEPENDS ON BOUNDARY CONDITIONS

DIFFERENTIAL EQUATION SET

$$K_i \frac{\partial R_i}{\partial t} = -V \frac{\partial R_i}{\partial x} + D \frac{\partial^2 R_i}{\partial x^2} - K_i \lambda_i R_i + K_{i-1} \lambda_{i-1} R_{i-1} \quad i = 1,n$$

with initial condition

$$R_i(x,0) = 0, \quad i = 1,n$$

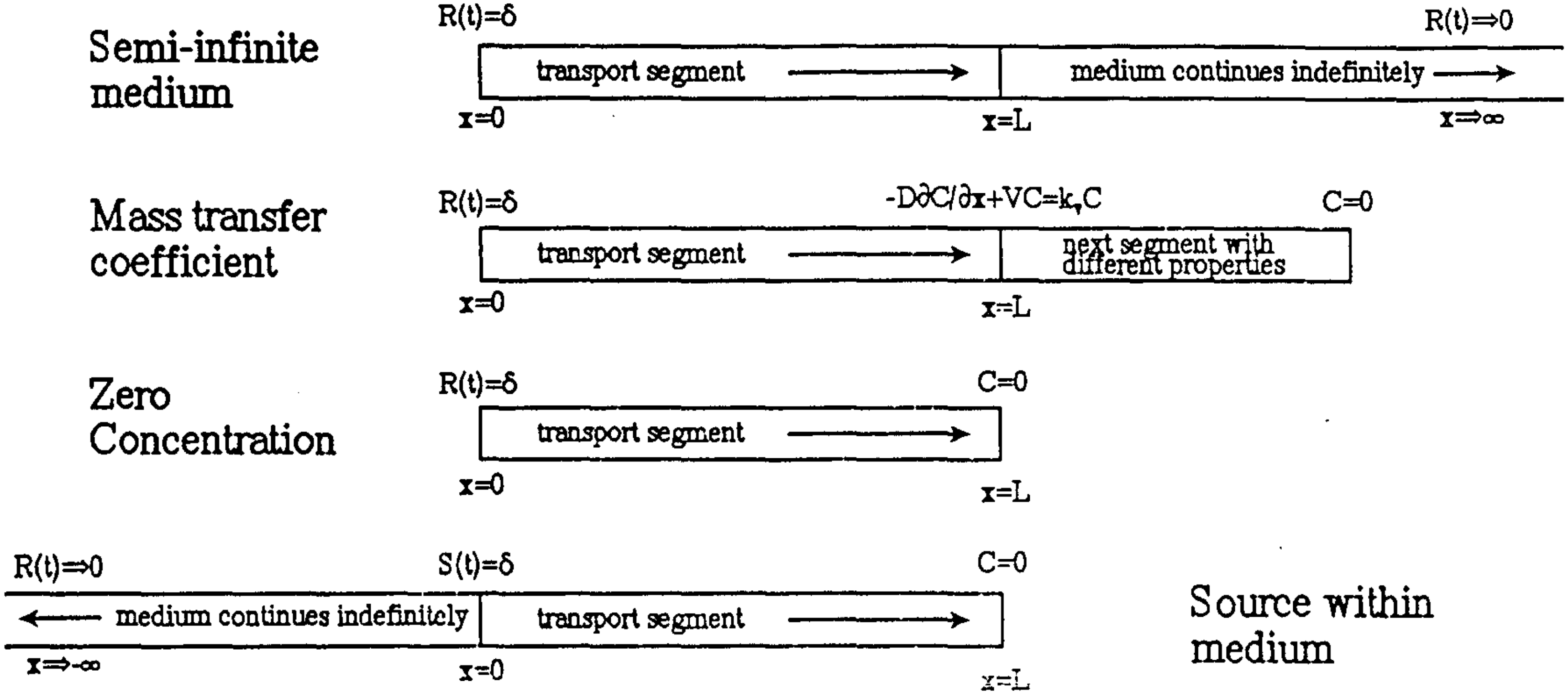
and boundary condition

$$R_i(0,t) = \delta_t, \quad i = 1$$

$$R_i(0,t) = 0, \quad i > 1$$

$$\lim_{x \to \infty} R_i(x,t) = 0, \quad i = 1,n$$

Solution published: Heinrich and Andres, Ann. Nucl. Energy, 12, 685, (1985)



Semi-infinite medium
R(t)=δ
R(t)⇒0
transport segment
medium continues indefinitely
x=0
x=L
x⇒∞
Mass transfer coefficient
R(t)=δ
-D∂C/∂x+VC=k_r C
C=0
transport segment
next segment with different properties
x=0
x=L
Zero Concentration
R(t)=δ
C=0
transport segment
x=0
x=L
R(t)⇒0
S(t)=δ
C=0
medium continues indefinitely
transport segment
x⇒-∞
x=0
x=L
Source within medium

CHEMICAL MODEL (SORPTION MODEL) FOR A SEGMENT

CONSTANT RETARDATION

K_d, K_a = f(basic parameters)

BASIC PARAMETERS

pH, Eh, $[Ca^{+2}]$, $[Na^{+}]$, $[CO_3^{-2}]$
Fe oxides, calcite, chlorite, etc.

$$[b_0 + b_1 x_1 + b_2 x_2 + b_{11} x_1^2 + b_{22} x_2^2 + b_{12} x_1 x_2]\,\Omega$$

- $x_1 = \log(TDS)$
- $x_2 = \log([RN])$
- Ω = uncertainty factor
- [RN] assigned by random numbers, adds extra uncertainty

Sorption Model

- Linear sorption from k_d values
- k_d calculated from salinity, redox state, mineralogy
- sorption data base for
  - 39 elements
  - 20 primary minerals, alteration minerals, and mineral assemblages
- calculated values summed over minerals weighted by mineral abundance
- calculated values have uncertainty applied

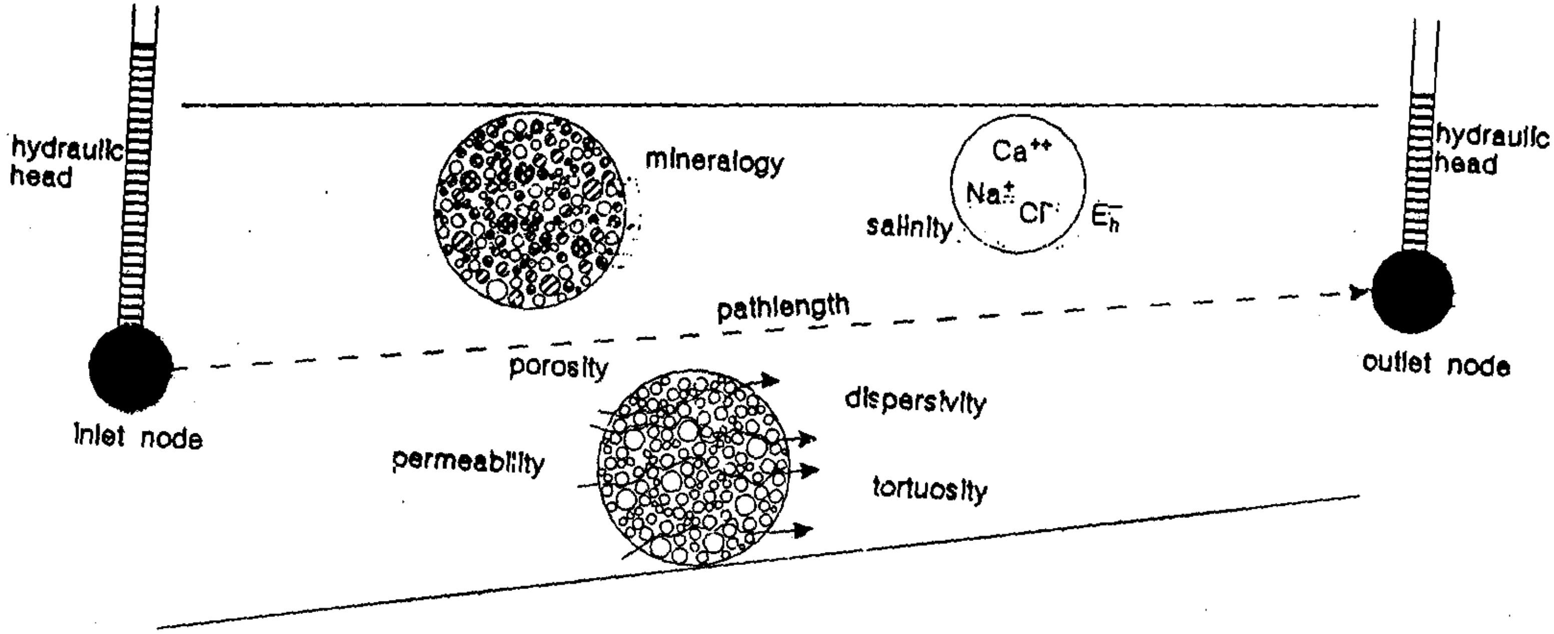


Illustration of the Principal Properties of a GEONET Transport Segment

Geosphere Modelling Approach

- can represent site specific conditions of any plutonic rock site on the Shield
- the modelling approach is generic

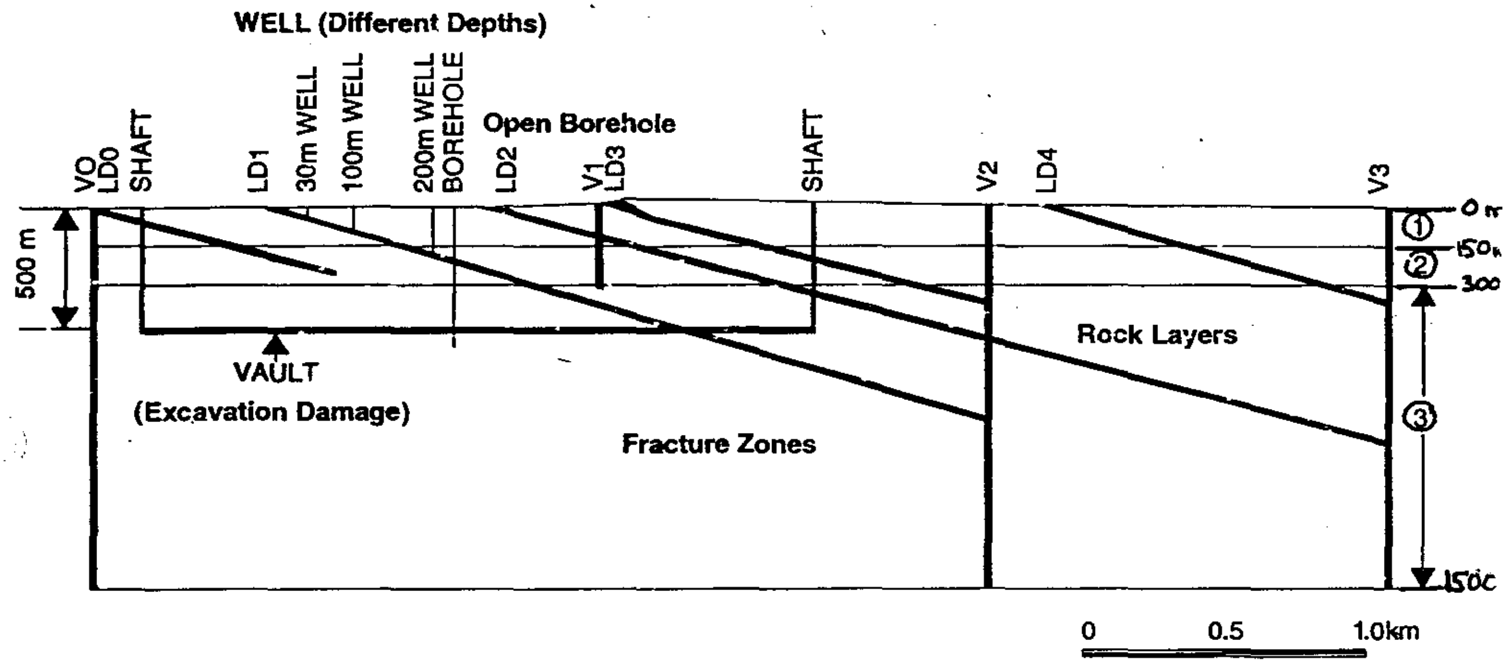
Geosphere Model Con't

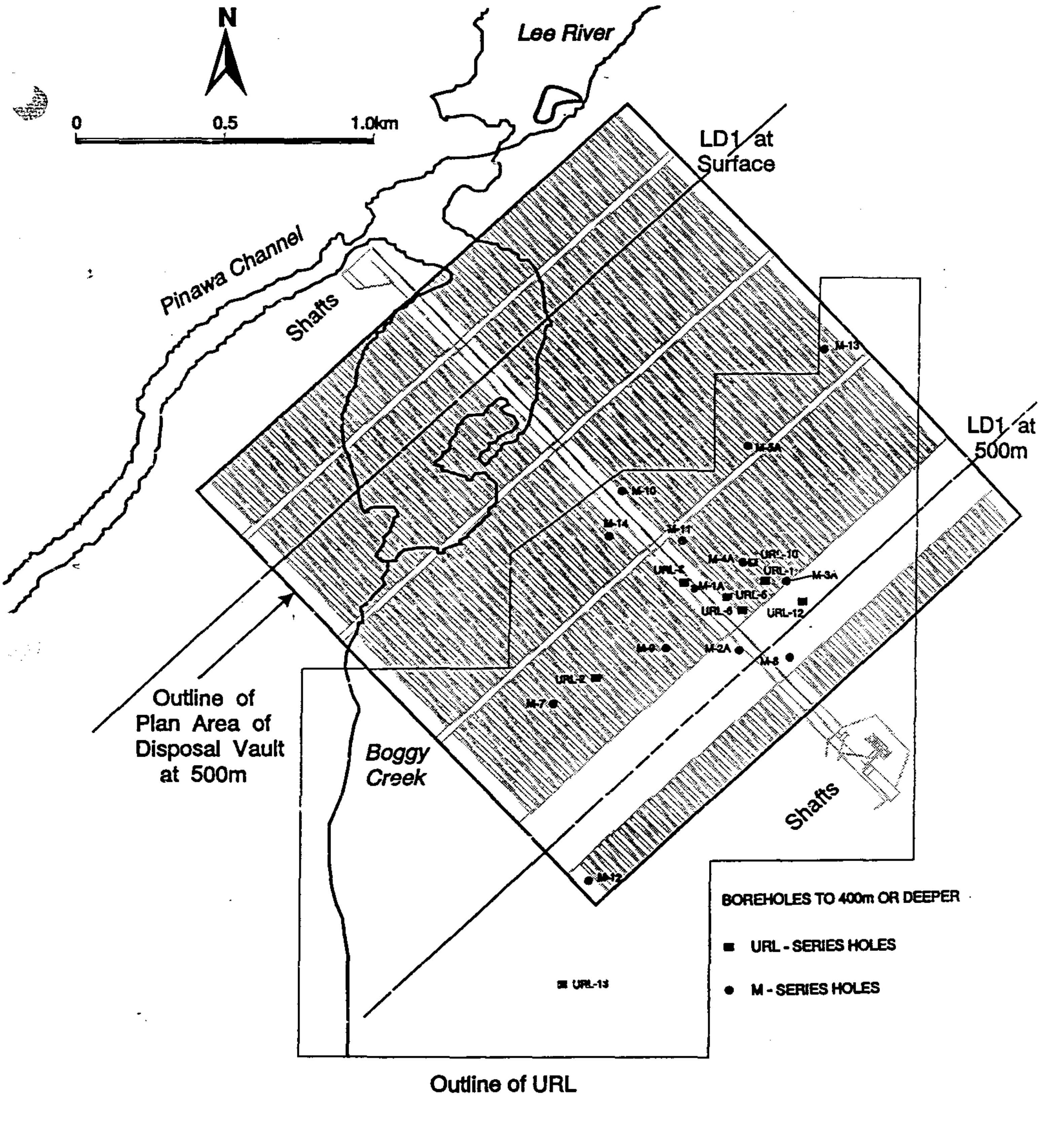
- The example we have used in the EIS postclosure assessment case study is site specific.
- Represents known or inferred conditions of a real site: the site of the URL at Whiteshell Research Area.
- Hypothetical disposal vault at 500 m depth.
- The case study model is not generic.

Geosphere Model - How is it used?

- calculates transport of vault contaminants through the geosphere
- establishes boundary conditions for vault model (source term)
- determines location and rate of discharge to biosphere
- overall system performance assessment
  - long term safety?
  - site specific/design specific constraints?

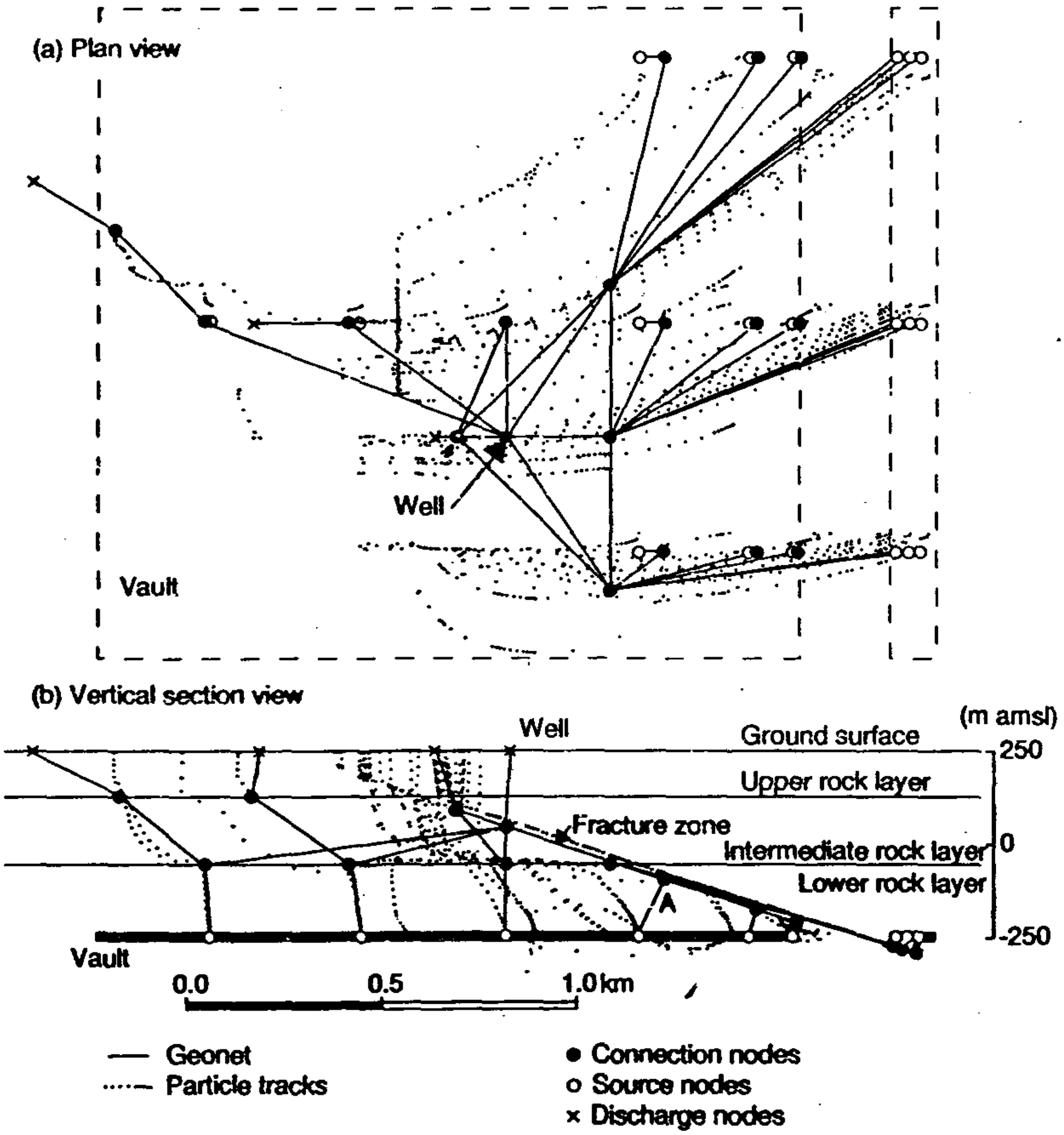
Summary of Structures and Features Included in EIS Geosphere Model





Location of EIS Case Study Disposal Vault and Area Characterized at URL Site

The Network of Pathways for GEONET



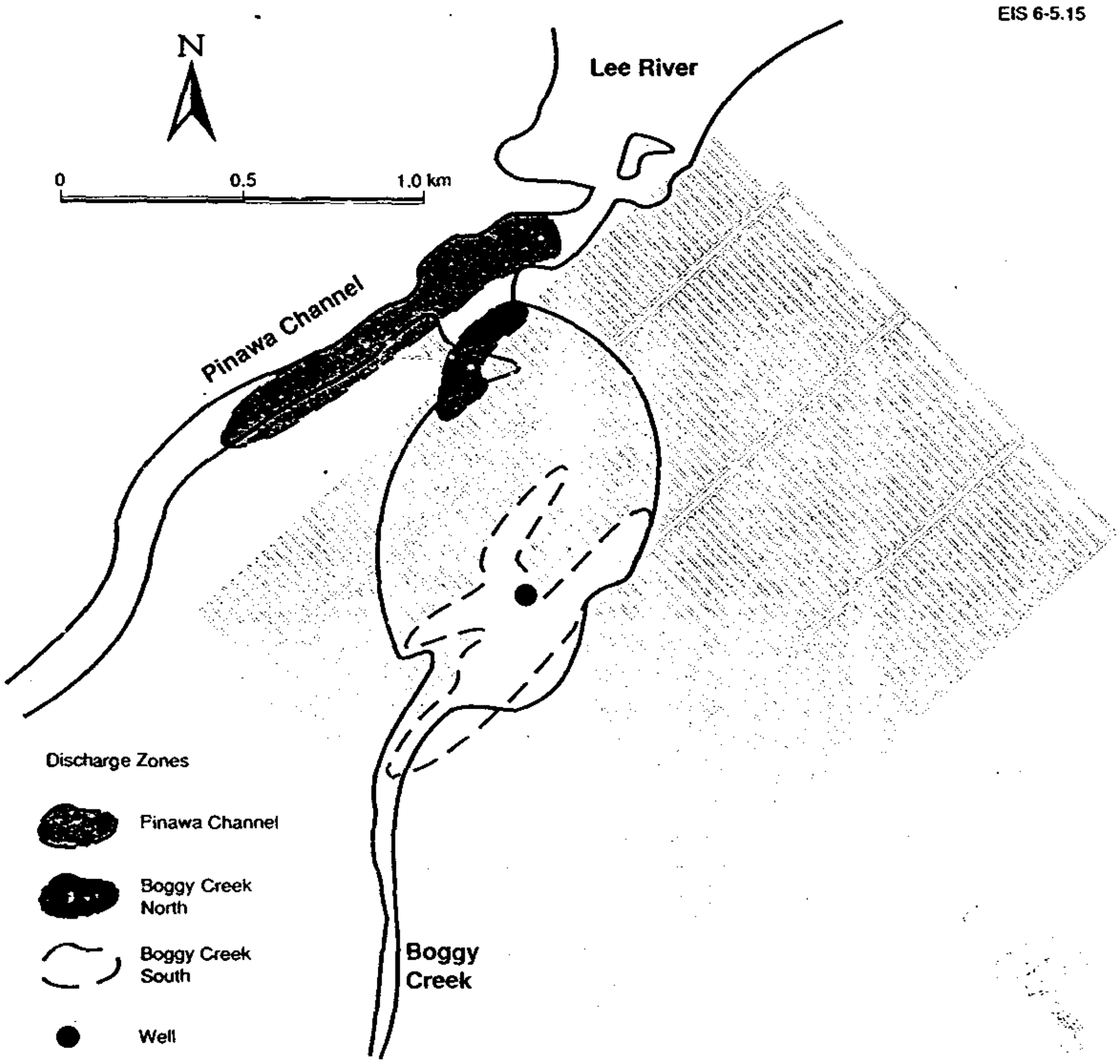


FIGURE 5-15: Discharge Zones in the Biosphere for the Reference Disposal System

The network of geosphere segments reaches the biosphere at four locations: Pinawa Channel, Boggy Creek South, Boggy Creek North and the well. The first three discharge zones are water bodies and wetlands in topographic lows.

We assume that the location of the well is constrained to lie along the centre of the contaminant plume moving up fracture zone LD1. The centre of this plume is offset from the centre line of the vault because of the direction of prevailing groundwater movement. Different well depths are modelled, with two general classes of wells: overburden and bedrock wells. We assume that overburden wells are relatively shallow and do not extend past the overburden overlying the rock of the geosphere. Bedrock wells are deeper, and we assume they are located such that they would intersect and draw water from LD1 as far down in the geosphere as possible. This figure and Figure 5-14 illustrate cases involving bedrock wells.

In this figure, the depth of the (bedrock) well is 37 m. For this depth, and with the constraint mentioned above, the well would lie within the current confines of Boggy Creek. This situation could occur sometime in the future if parts of Boggy Creek become filled with sediment or if water levels fall. We have assumed the constraint on the well location (along the centre of the contaminant plume) so as to overestimate subsequent estimates of dose.

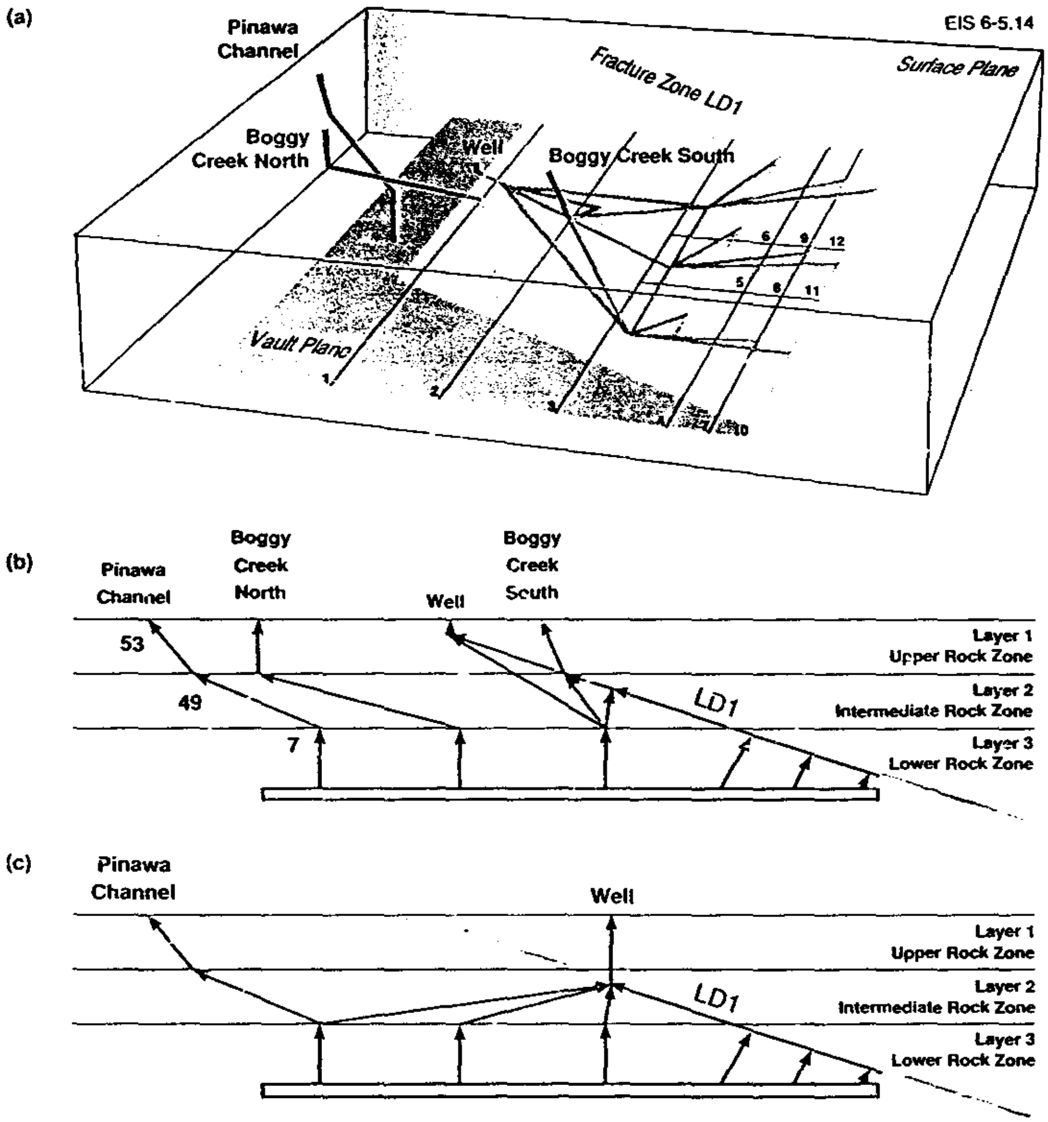


FIGURE 5-14: The Network of Segments Used by GEONET for the Reference Disposal System

Parts (a) and (b) apply to the case with small to moderate rates of withdrawal of water from a shallow bedrock well. Part (c) applies to the limiting case where withdrawal rates are large and from a deep bedrock well.

- Part (a) illustrates the set of segments leading from 12 vault sectors to 4 discharge locations in the biosphere. The shaded structure extending upwards from the lower right-hand corner represents fracture zone LD1. Segments within LD1 converge to discharge into Boggy Creek South and the well.
- Parts (b) and (c) are cross sections with projections of the transport network. The arrows indicate the direction of contaminant transport; for example contaminants leaving vault sector 1 travel along the segments numbered 7, 49 and 53, and end at the discharge location labelled Pinawa Channel. Contaminants released from other vault sectors discharge into Boggy Creek North, Boggy Creek South or the well.

The well receives more of the contaminants in part (c). In this limiting case of large rates of water withdrawal, the figure shows that contaminants no longer discharge to Boggy Creek North or Boggy Creek South, and that some contaminants are diverted to the well from the discharge at Pinawa Channel. There is a gradual diversion of contaminant movement from the set of segments shown in part (b) to those shown in part (c), depending on the rate of water withdrawal from the well.
The complete transport network used by GEONET to represent the reference disposal system has 46 segments, with 16 used to describe transport along LD1 (Davison et al. 1994b).

Uncertainty and Variablity in Geosphere Model

- hydrogeology
  - spatial variability in structures and properties explicitly represented
  - parameters held contant at values used in detailed groundwater flow modelling
  - uncertainty expressed through random variation in only few parameters
  - dispersivities given wide range of uncertainty
- geochemistry
  - spatial variability in salinity, redox, mineralogy explicitly represented and also given randomly varying (uncertain) values
  - sorption related to salinity, redox and mineralogy but random variation (uncertainty) applied to sorption relationship

Interface to Vault Model

Data Passed from Geosphere to Vault

- Groundwater flow in buffer (set to zero)
- Groundwater flow in backfilled drifts (based on groundwater flow in nearby rock)
- properties of adjacent rock
  - groundwater flow rates
  - distance to more dilute groundwater
  - dispersion coefficient
  - sorption properties

Interface to Biosphere Model

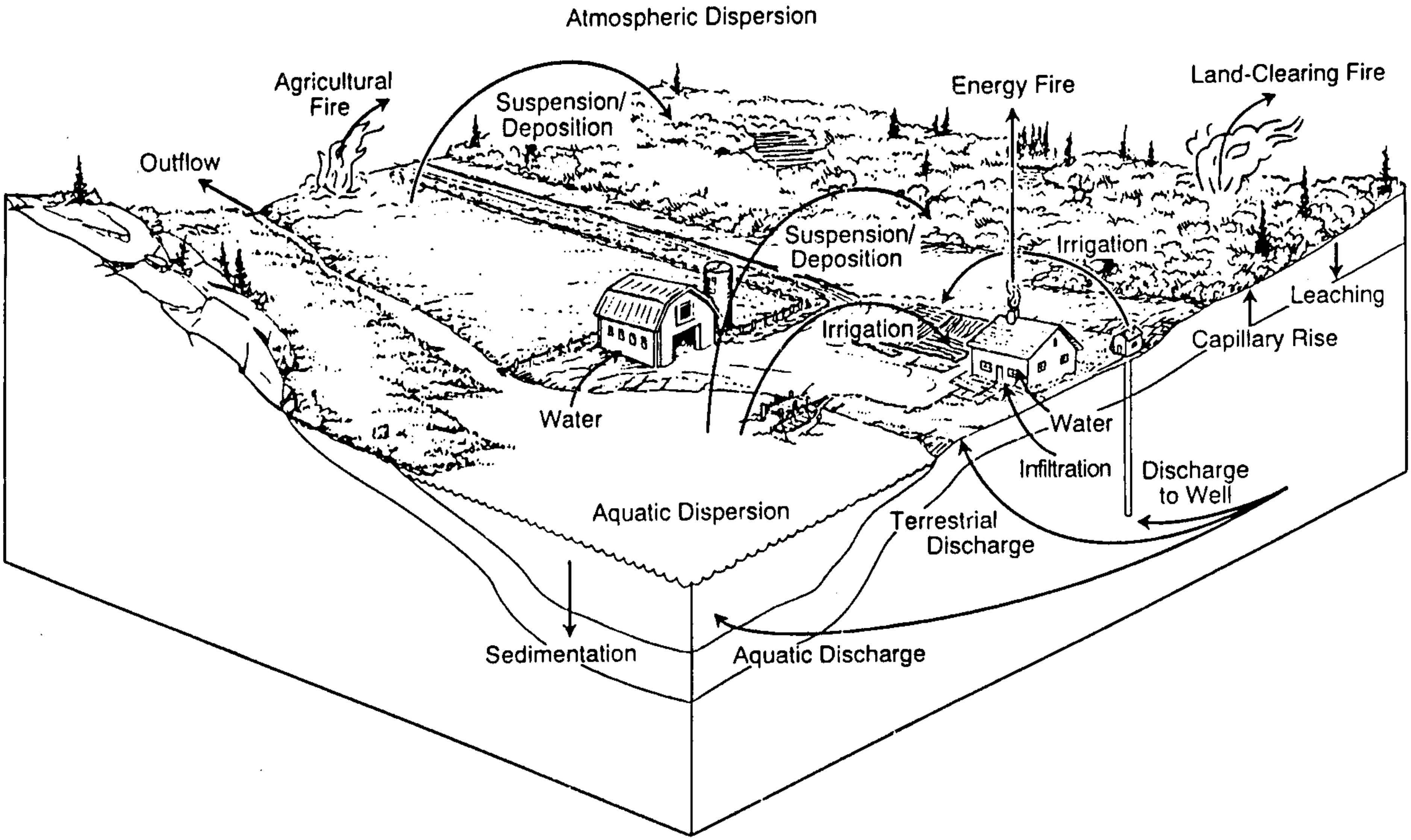
- Data Passed from Geosphere to Biosphere
  - Well Capacity
  - Areas of Discharges
  - Volumes of Discharging Groundwater
  - Sorption Properties in Near-Surface Layers

- Data Passed from Biosphere to Geosphere
  - Well Demand

CC3

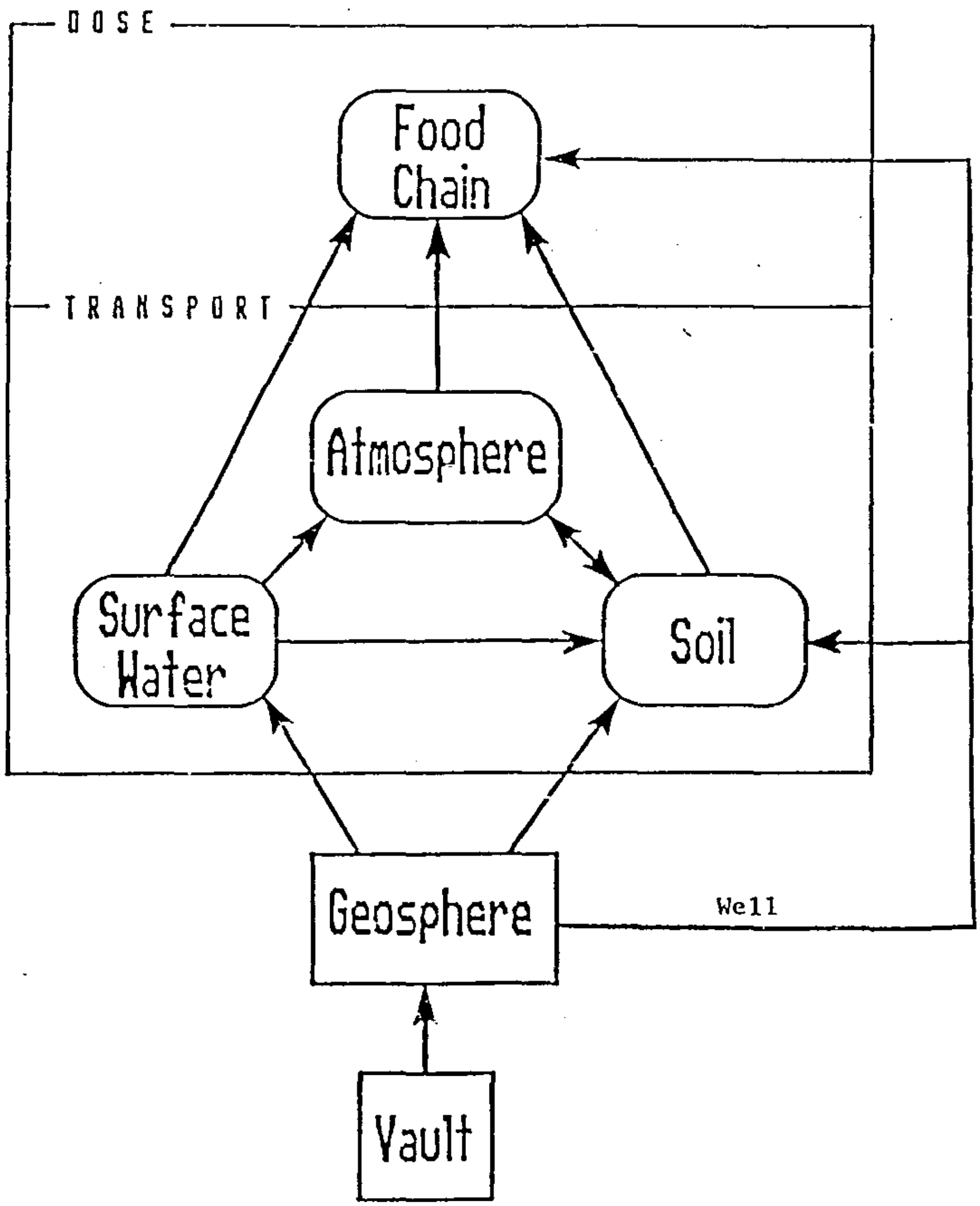
BIOSPHERE

MODEL

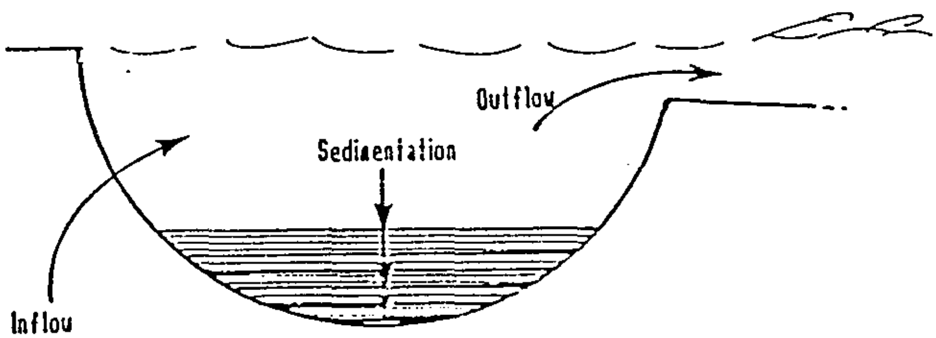


Atmospheric Dispersion
Agricultural Fire
Suspension/ Deposition
Energy Fire
Land-Clearing Fire
Outflow
Suspension/ Deposition
Irrigation
Leaching
Irrigation
Capillary Rise
Water
Water
Infiltration
Discharge to Well
Aquatic Dispersion
Terrestrial Discharge
Sedimentation
Aquatic Discharge

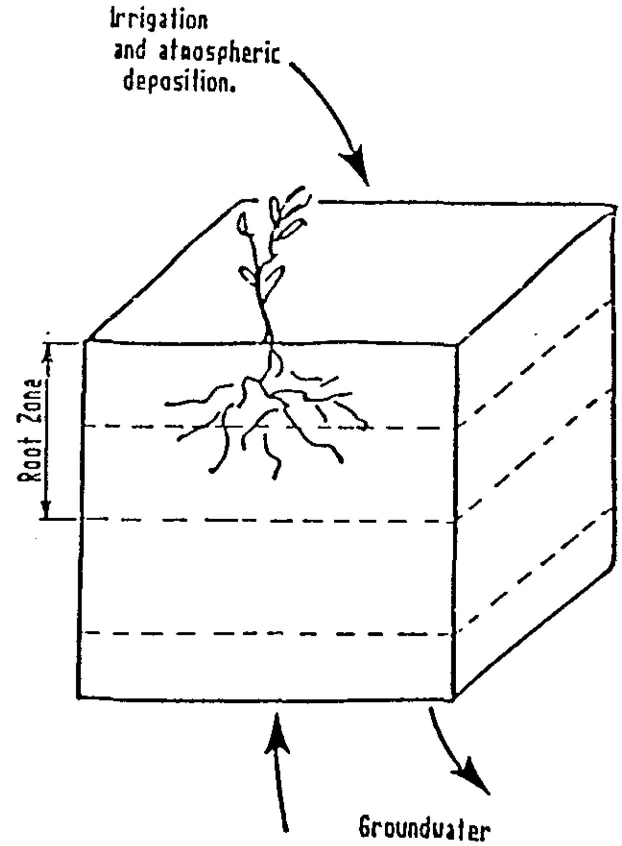
CC3 Biosphere



LAKE MODEL

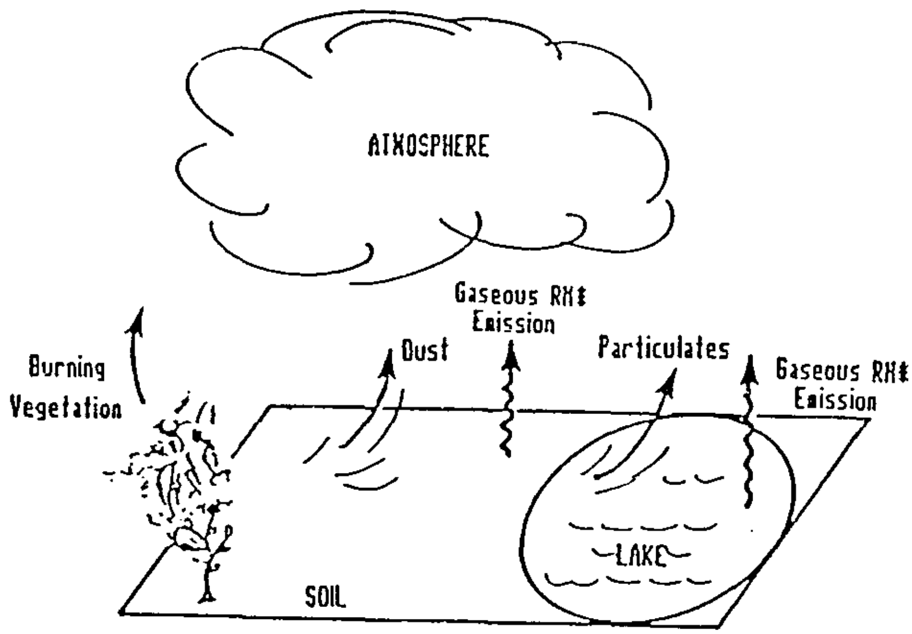


SOIL MODEL


Irrigation
and atmospheric
deposition.
Root Zone
Groundwater

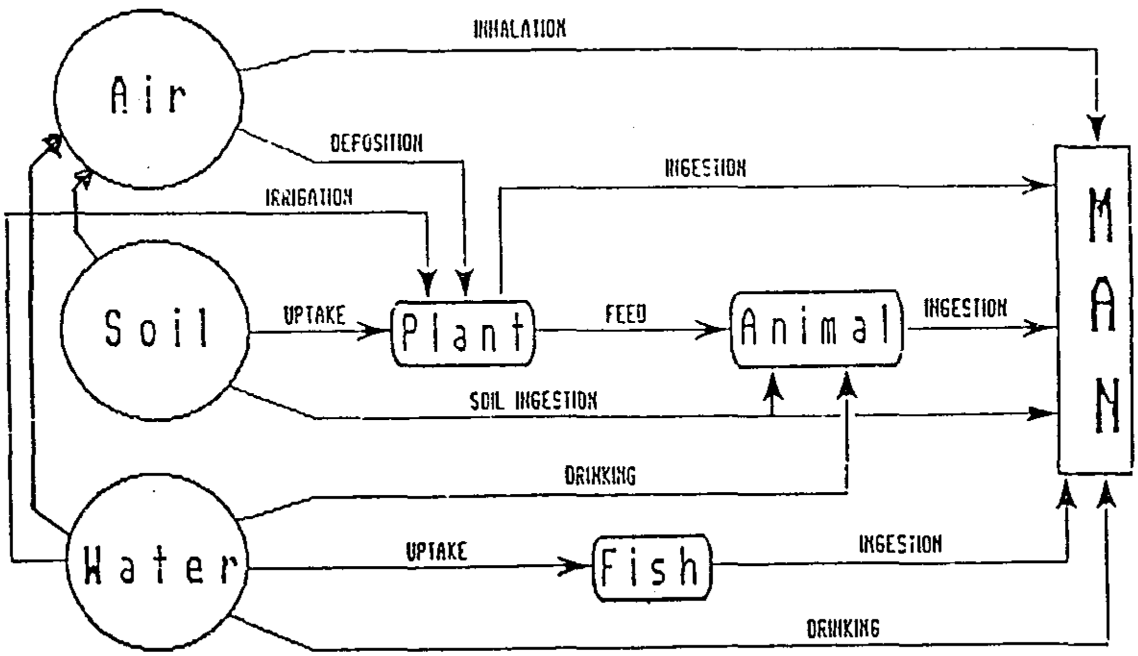
WNRE	SYVAC WORKSHOP	ESAB
Sec 6.2	Recent Applications of SYVAC3	Fig 35

ATMOSPHERE MODEL

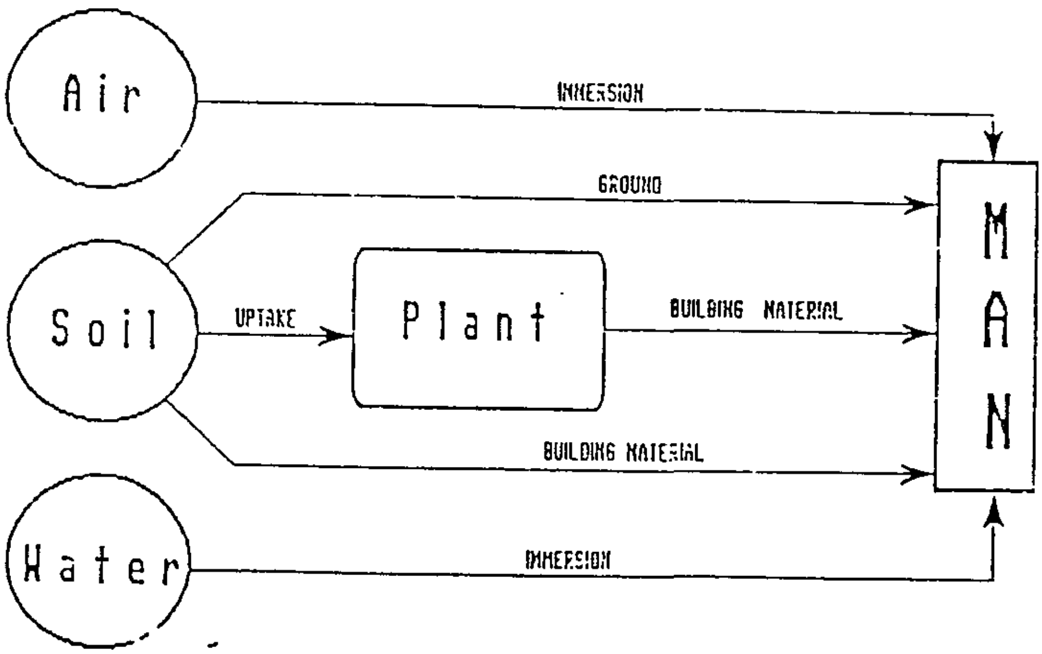


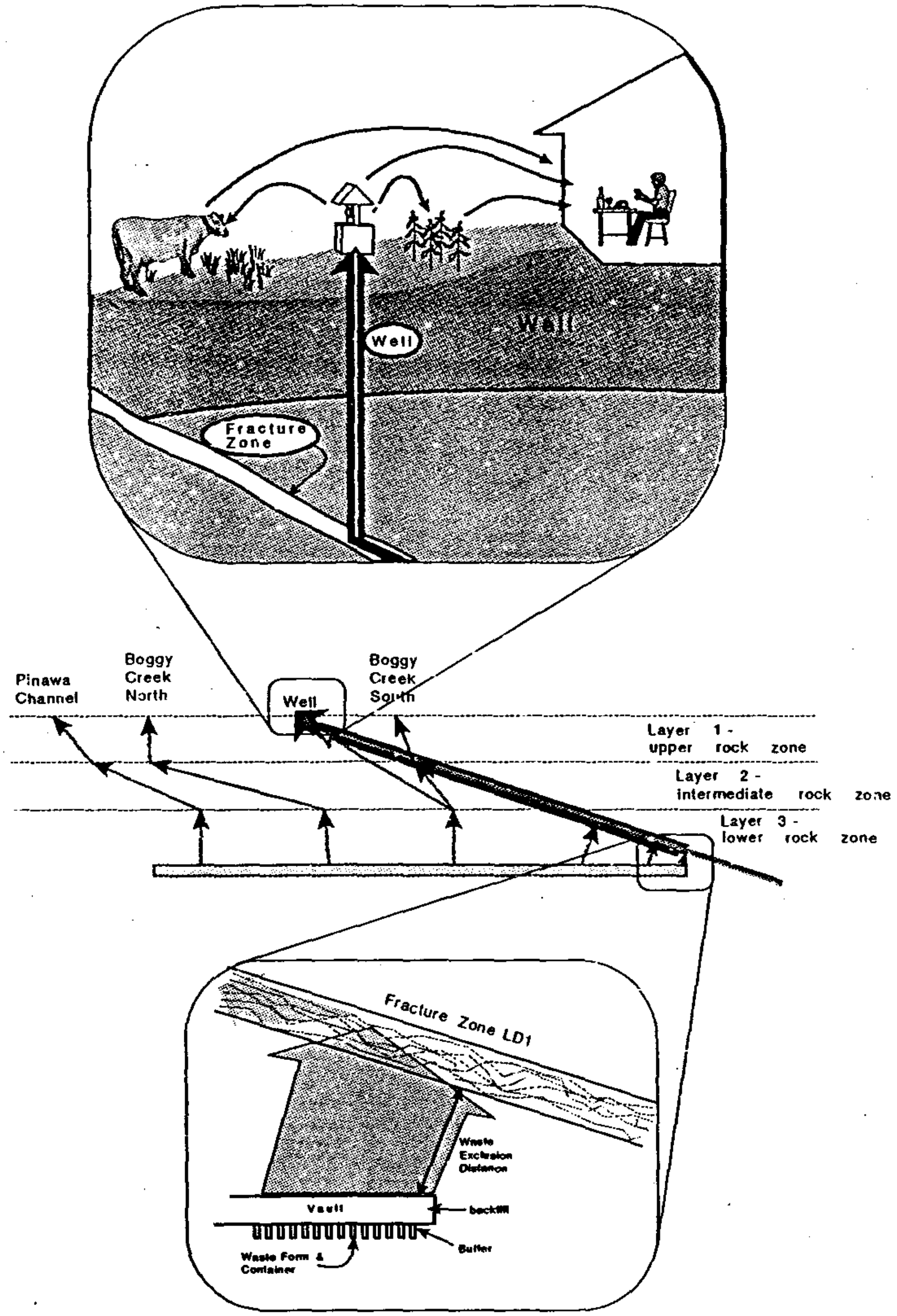
* ^{222}Rn and ^{129}I.

INTERNAL EXPOSURE PATHWAYS



EXTERNAL EXPOSURE PATHWAYS




Well
Fracture Zone
Well
Pinawa Channel
Boggy Creek North
Well
Boggy Creek South
Layer 1 - upper rock zone
Layer 2 - intermediate rock zone
Layer 3 - lower rock zone
Fracture Zone LD1
Waste Exclusion Distance
Vault
backfill
Buffer
Waste Form & Container