U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD
PANEL ON STRUCTURAL GEOLOGY & GEOENGINEERING

SUBJECT: HYDROLOGIC GOALS AND REQUIREMENTS FOR SELECTED SEALING COMPONENTS

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Goals and Design Requirement Types

Hydrologic--Majority of Sealing Components

- Establish design basis
- Determine anticipated and unanticipated water inflows

Hydrologic--Channels and Sumps

- Variable

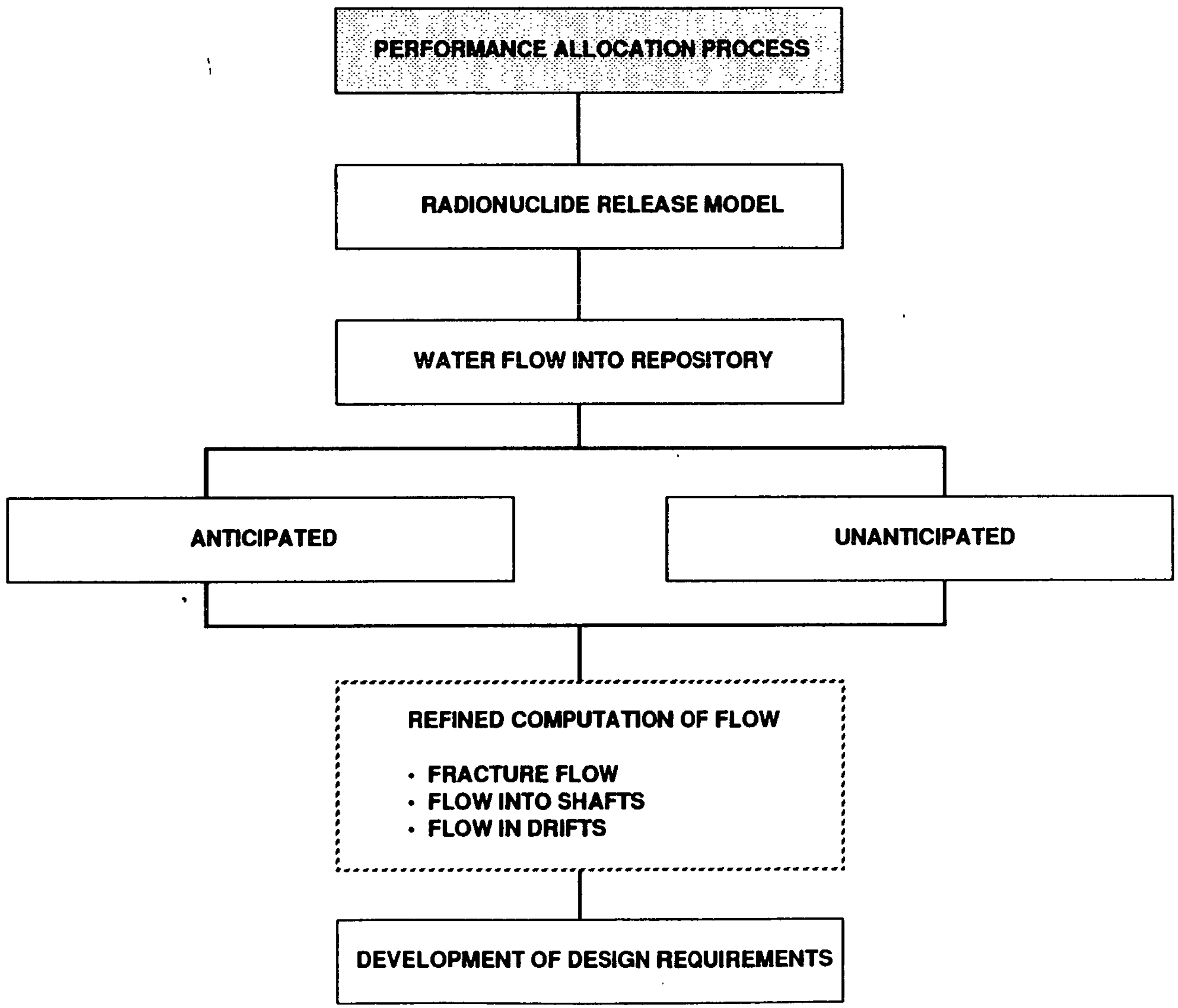
Hydrologic--Borehole

- Preferential release

Airborne--Shaft, Ramp, Drift Fills

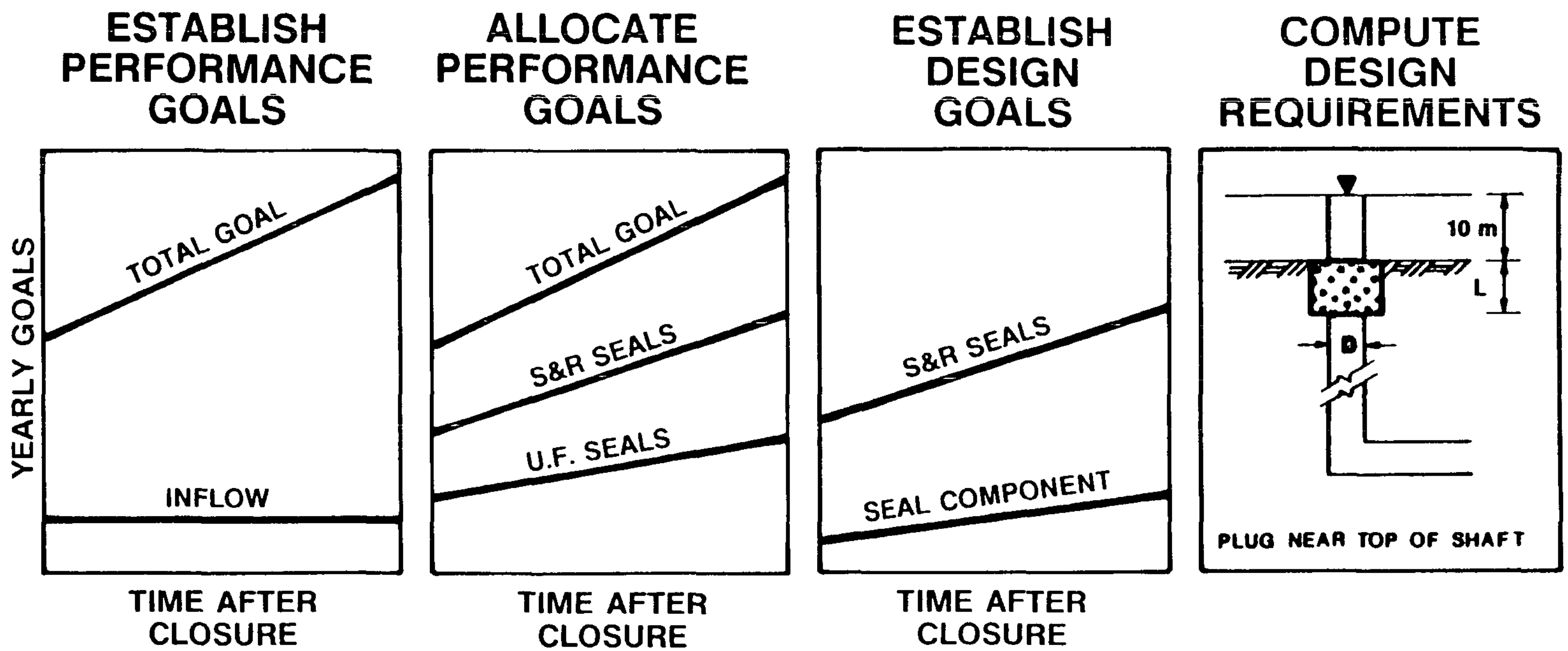
- Determine percentage of flow through shafts, ramps, and rock (convective airflow)
- Determine preferential release (barometric airflow)

Scope of Presentation

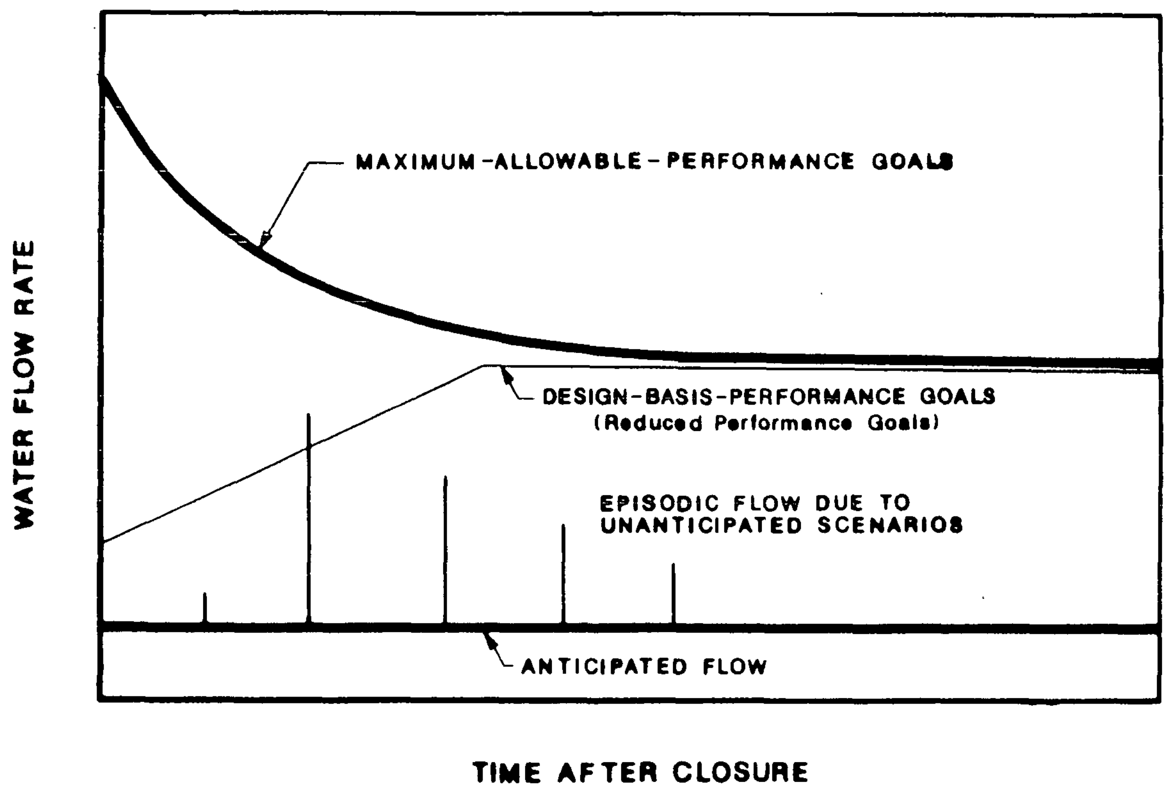


Conceptualization of Performance Allocation Process For Seals

(WATERBORNE RADIONUCLIDE RELEASE)



Establish Performance Goals



Allocate Performance

Time	Allowable Amount of Water Passing Sealing Components and Contacting Waste: TOTAL		UNDERGROUND SEALS		SHAFT AND RAMP SEALS
1	1,000 m^3	=	900 m^3	+	100 m^3
2	10,000 m^3	=	5,000 m^3	+	5,000 m^3
3	100,000 m^3	=	5,000 m^3	+	95,000 m^3

Establish Design Goals

$$S(t) = X_s \, DG_s(t) - C_s(t)$$

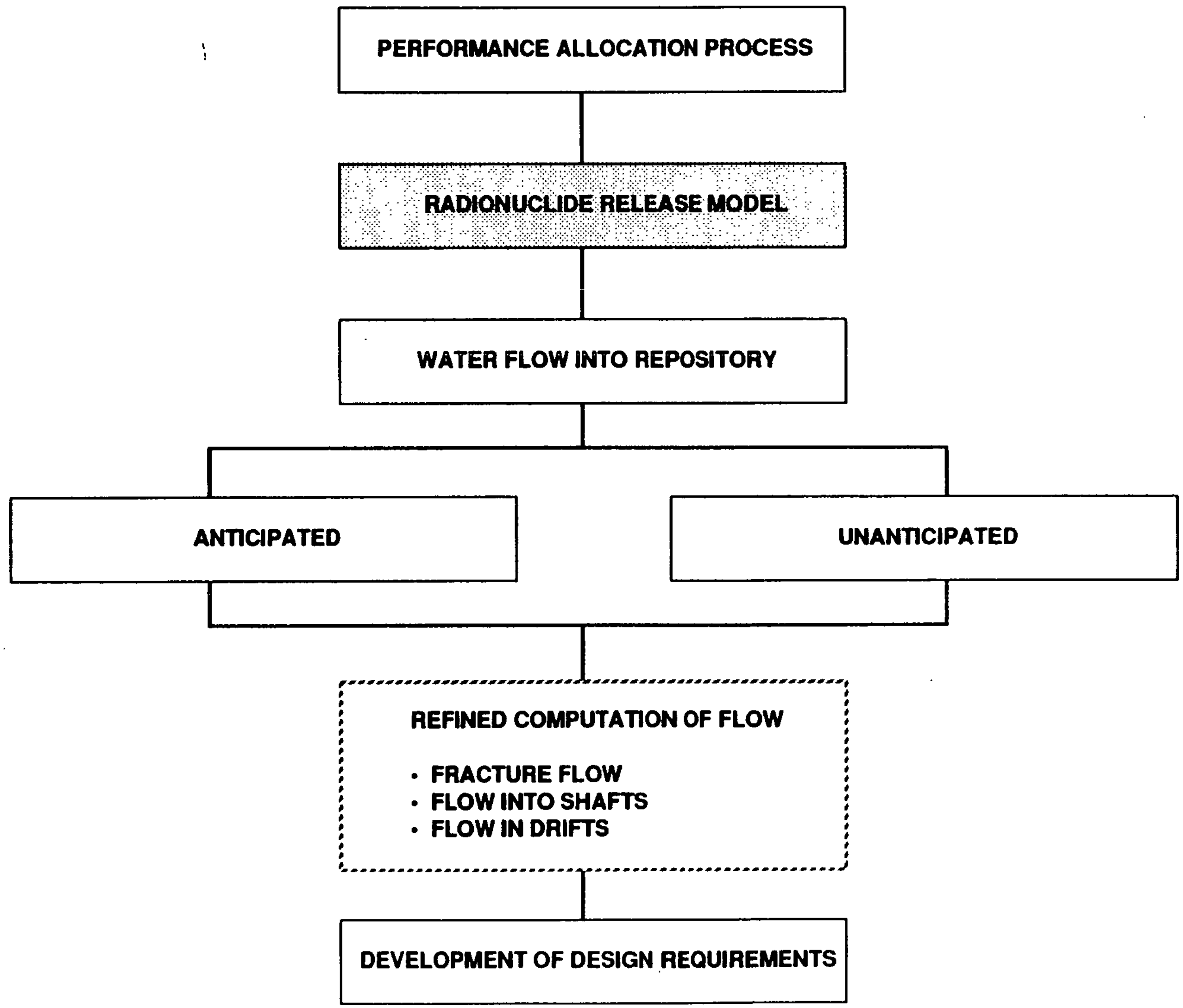
and

$$U(t) = X_u \, DG_u(t) - C_u(t)$$

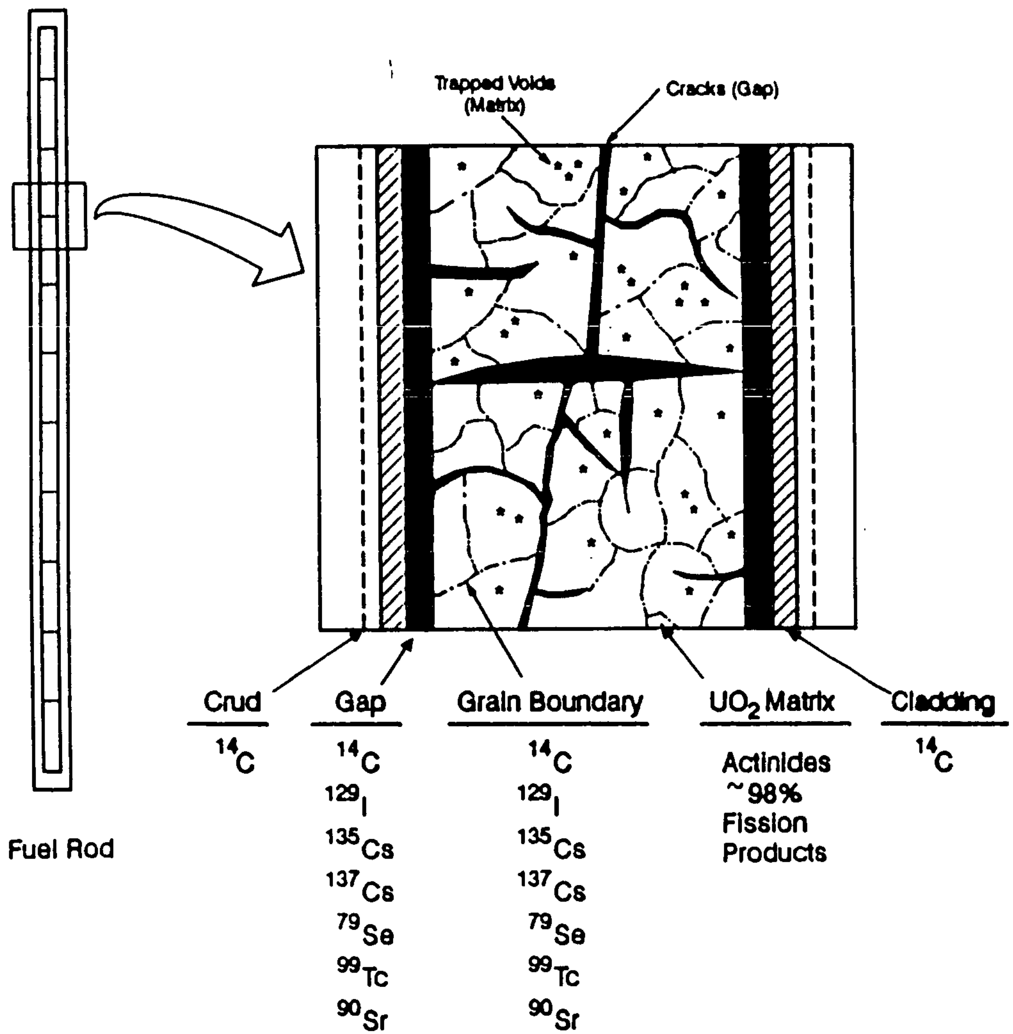
where

$S(t)$	= performance goal for shaft and ramp subsystem,
$U(t)$	= performance goal for the underground facility subsystem,
$C_s(t)$	= storage capacity for the shaft and ramp subsystem,
$C_u(t)$	= storage capacity for the underground facility subsystem,
X_s, X_u	= number of a specific sealing component in either subsystem in which some level of performance is required, and
$DG_s(t)$, $DG_u(t)$	= design goal for a specific sealing component in either subsystem.

Scope of Presentation



Radionuclide Release Model



(Apted et al., 1989)

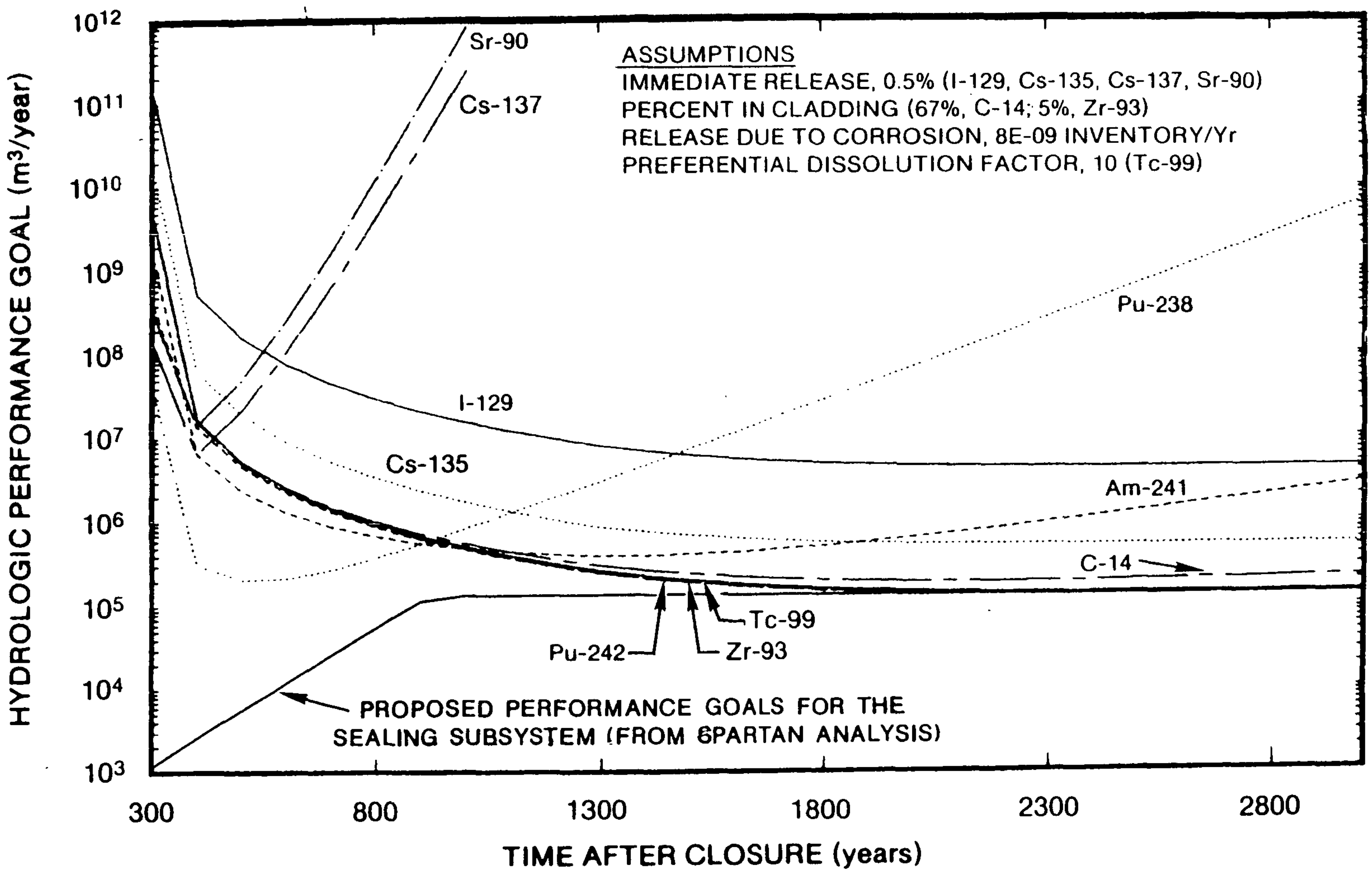
Model 1

- Congruent dissolution
- All radionuclides in matrix

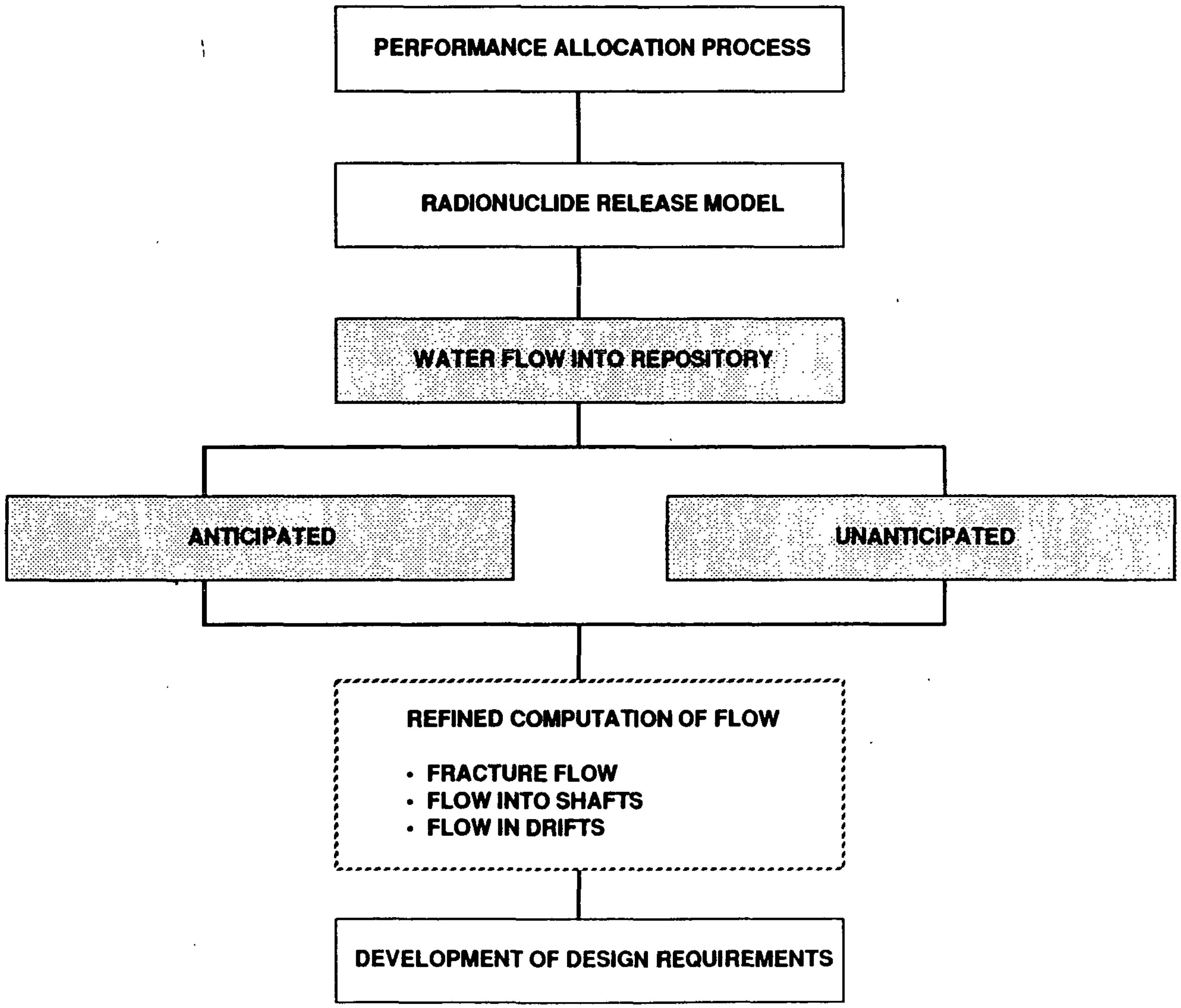
Model 2

- Radionuclides distributed in
  - matrix
  - cladding and structural parts
  - gap
  - grain boundaries
- Mechanisms considered
  - congruent dissolution
  - corrosion of zircaloy cladding
  - rapid gas release
  - preferential dissolution

Development of Performance Goals



Scope of Presentation



Types of Flow Considered

Anticipated

- Matrix flow over entire repository area
- Annual, limited, and localized fracture flow
- Limited surface flow into shafts

Unanticipated

- Continuous fracture and matrix flow over entire repository area
- Extensive surface flow into shafts from major flooding events

Flow Into Shafts

Assumptions

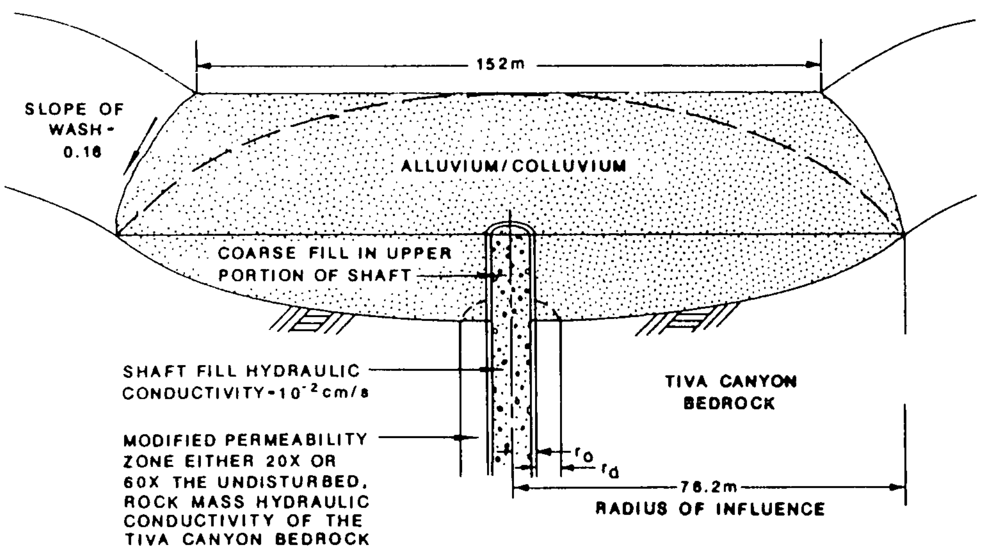
Anticipated

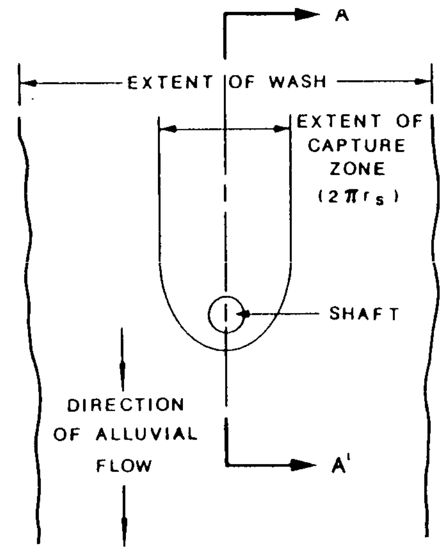
- No restriction of flood waters near shafts
- Shaft fill, granular 10^{-2} cm/s
- No seals in shafts
- Water supply--4 thunderstorms >1.3 cm (0.5 in)
- Duration of thunderstorm, 1 hour Sheet flow lasts 1 hour over shafts and faults

Unanticipated

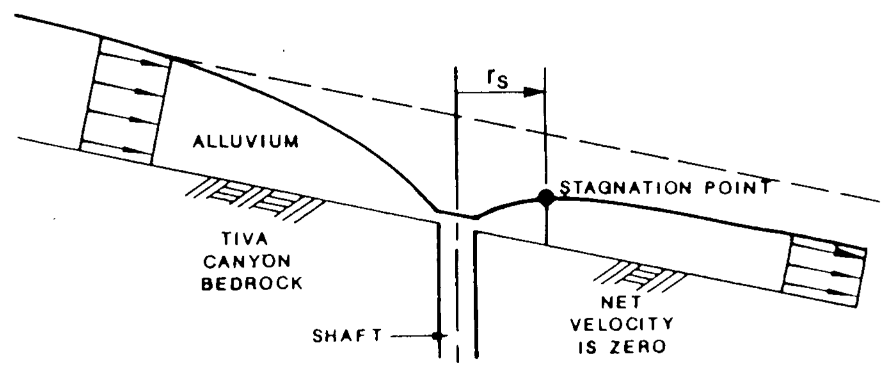
- Restriction of all flood waters at shafts
- Shaft fill, granular 10^{-2} cm/s
- No seals in shafts
- Water supply--PMF and 500 year flood
- No restriction on duration of flow into shafts

Models Used to Compute Flow Into Shafts (Unanticipated Conditions)





(a) PLAN VIEW
(Not to Scale)



(b) ELEVATION VIEW A-A'

Flow Into Shafts

Anticipated

Approach

Green and Ampt Solution

Results

Range 13.4 m^3/yr to 106 m^3/yr
Total for 4 shafts--270 m^3/yr

Unanticipated

Approach

Model 1--4 flows
- Dupuit
- Alluvial
- Tiva Canyon
- MPZ and shaft

Tiva Canyon range K_{SAT} 10^{-5} to 10^{-2} cm/s
Alluvium K_{SAT} 10^{-5} to 10^{2} cm/s
2 MPZ models

Results

PMF 200 to 83,700 m^3
for all shafts

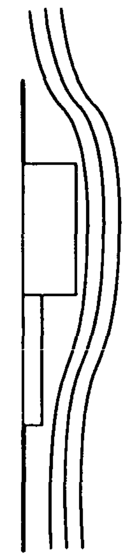
Flow Into Underground Facility

Anticipated

Approach: Matrix flow

Unsaturated zone modeling with drift filled with clay or sand

Result



Clay--
Flux 1.3 x 10^{-12} m^3/s
Total 5 m^3 /yr

Sand--
9.7 x 10^{-15} m^3/s
0.1 m^3/yr

Approach: Fracture flow

Green and Ampt Solution
- **Partially convergent water flow into 24 emplacement drifts**
- **2 water-producing faults in each ramp**
- **Fault properties varied**

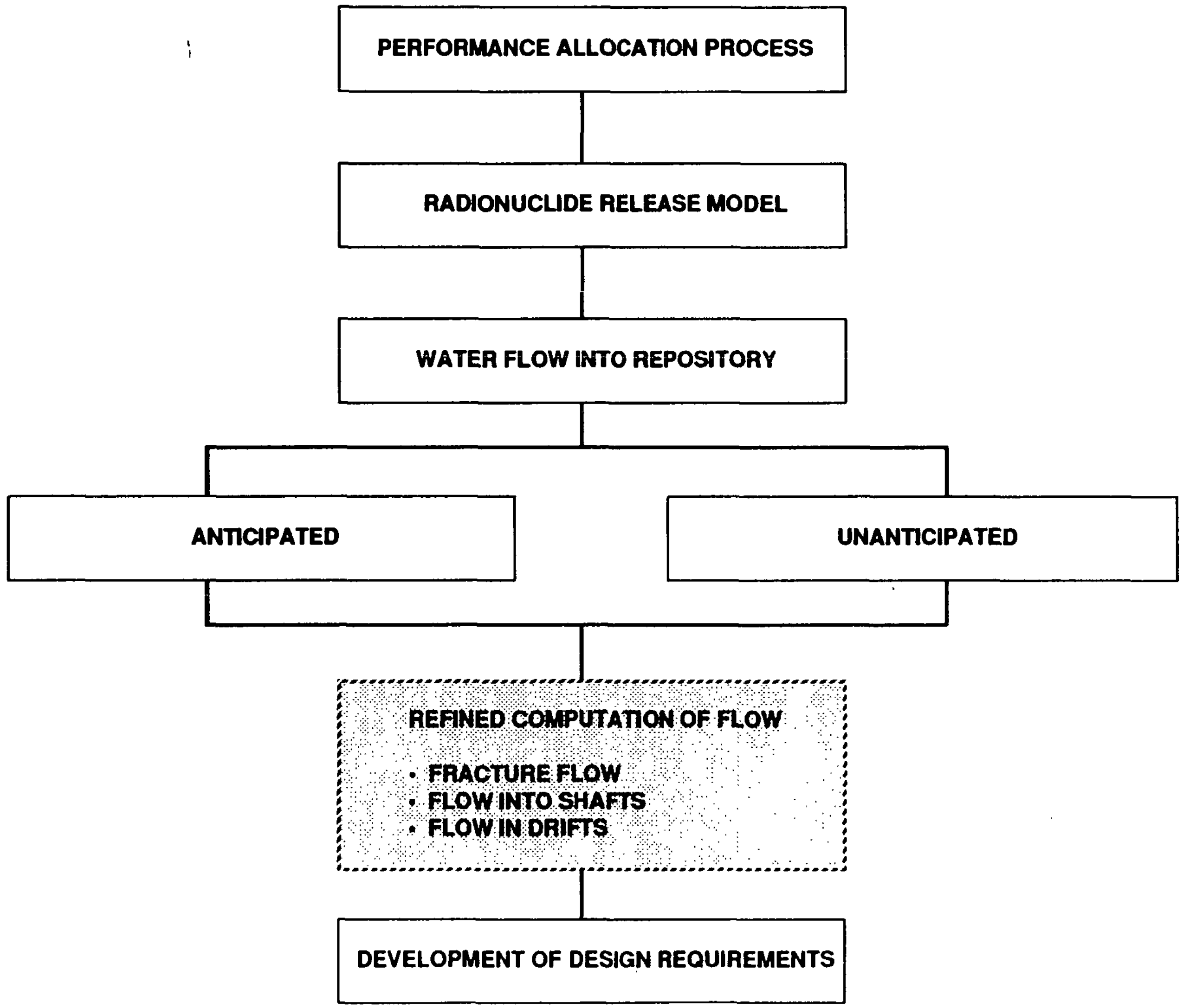
Result

62 m^3/yr

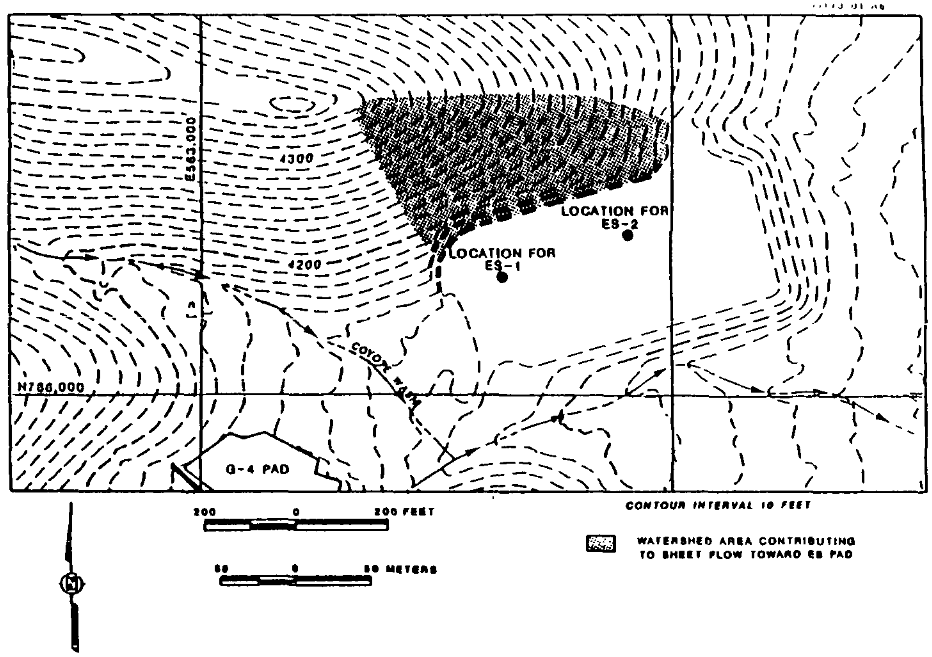
Unanticipated

Fracture and matrix flow 1mm/yr infiltration over total floor and ramp area-- 5600 m^3 /yr

Scope of Presentation



Fracture Flow Scenarios and Variables Considered



Scenarios

- Rainfall
- Sheetflow
- Channel flow

Conditions Considered

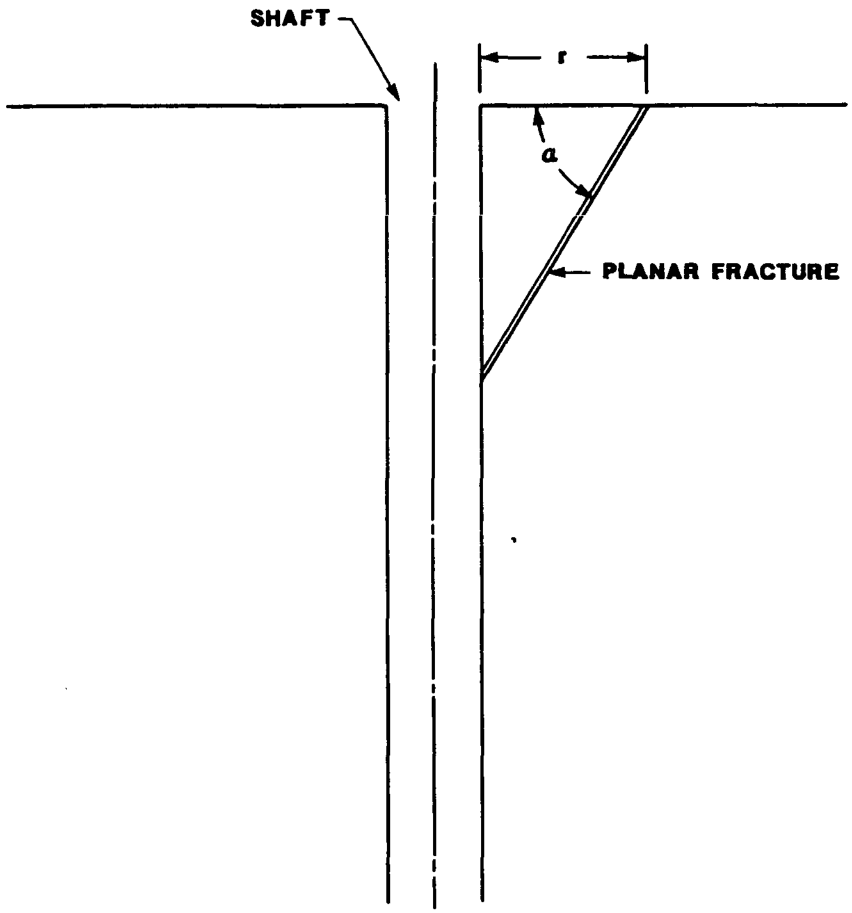
2 PMFs

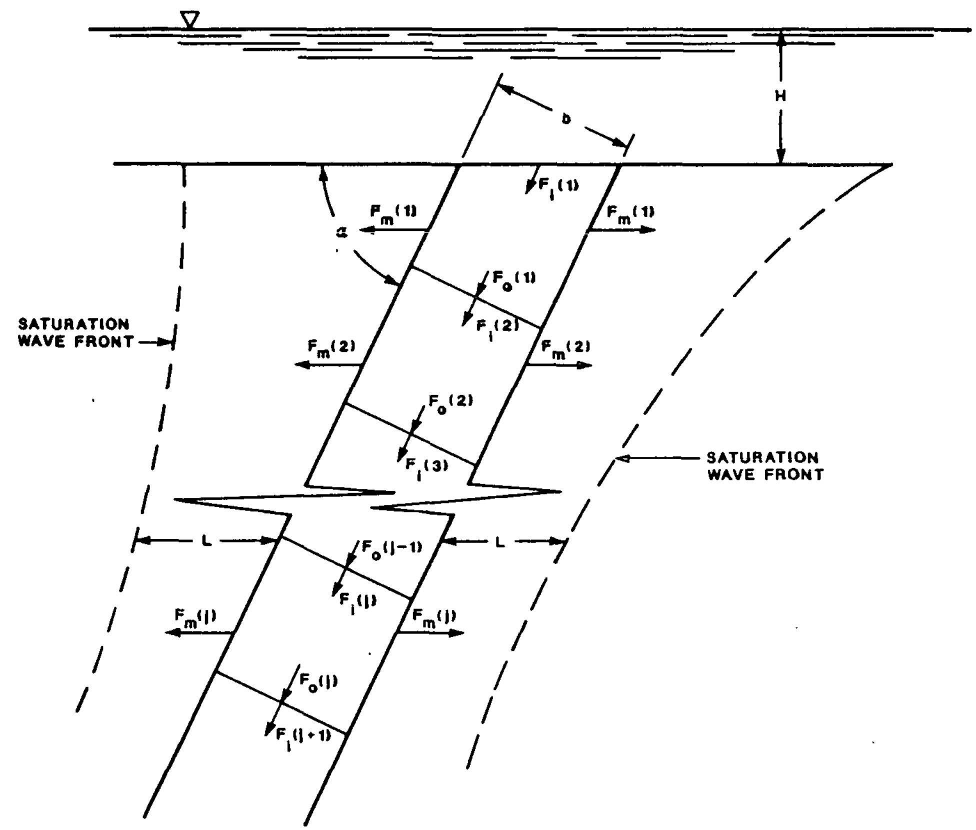
- General storm
- Thunderstorm

Rock properties

- Average imbibition
  S = 67% ε = 11%
- Maximum imbibition
  S = 44% ε = 15%
- Minimum imbibition
  S = 90% ε = 7%

Near-Surface Fracture Flow





Zones of Influence--General Storm PMF Channel and Sheet Flow

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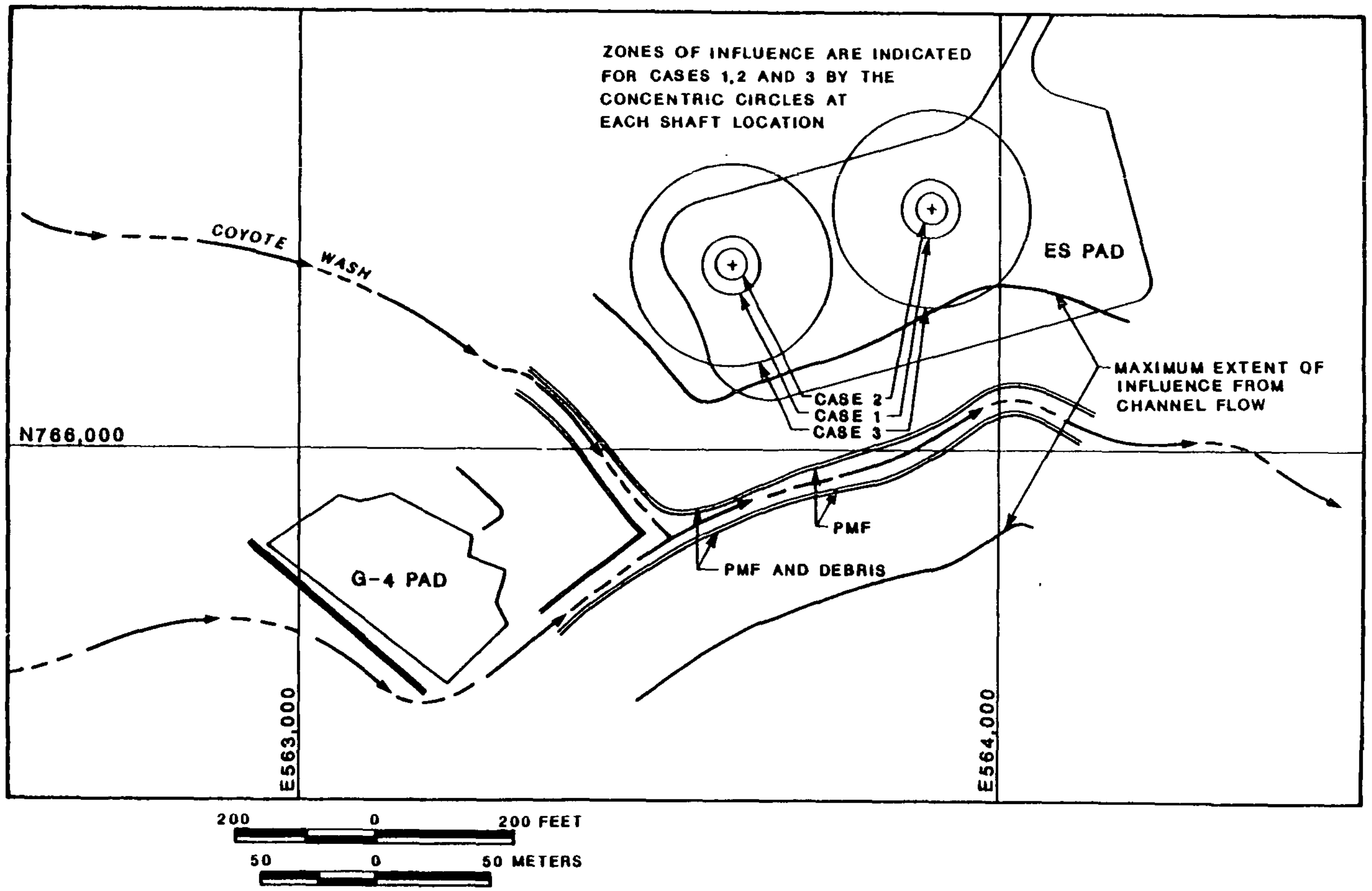
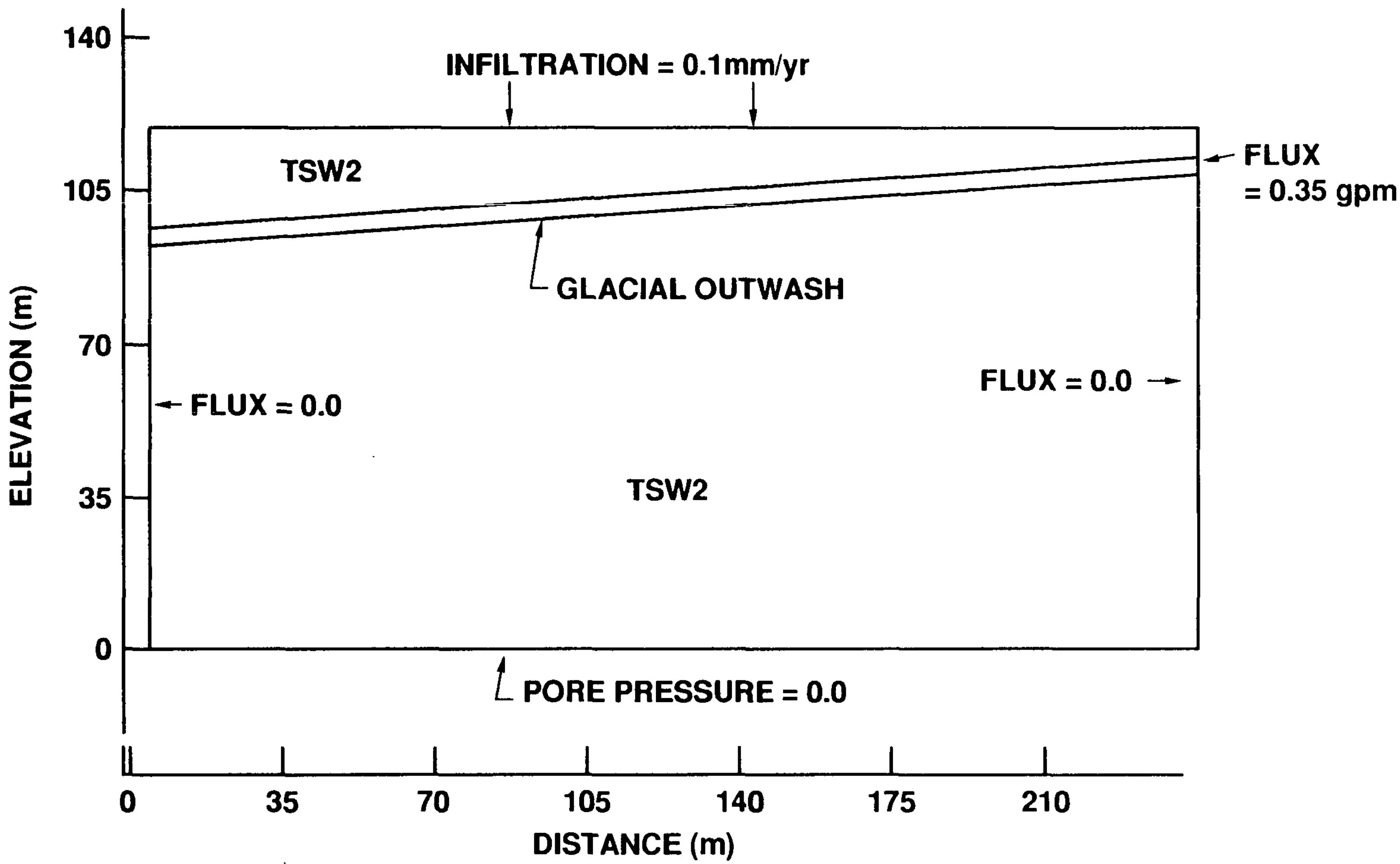
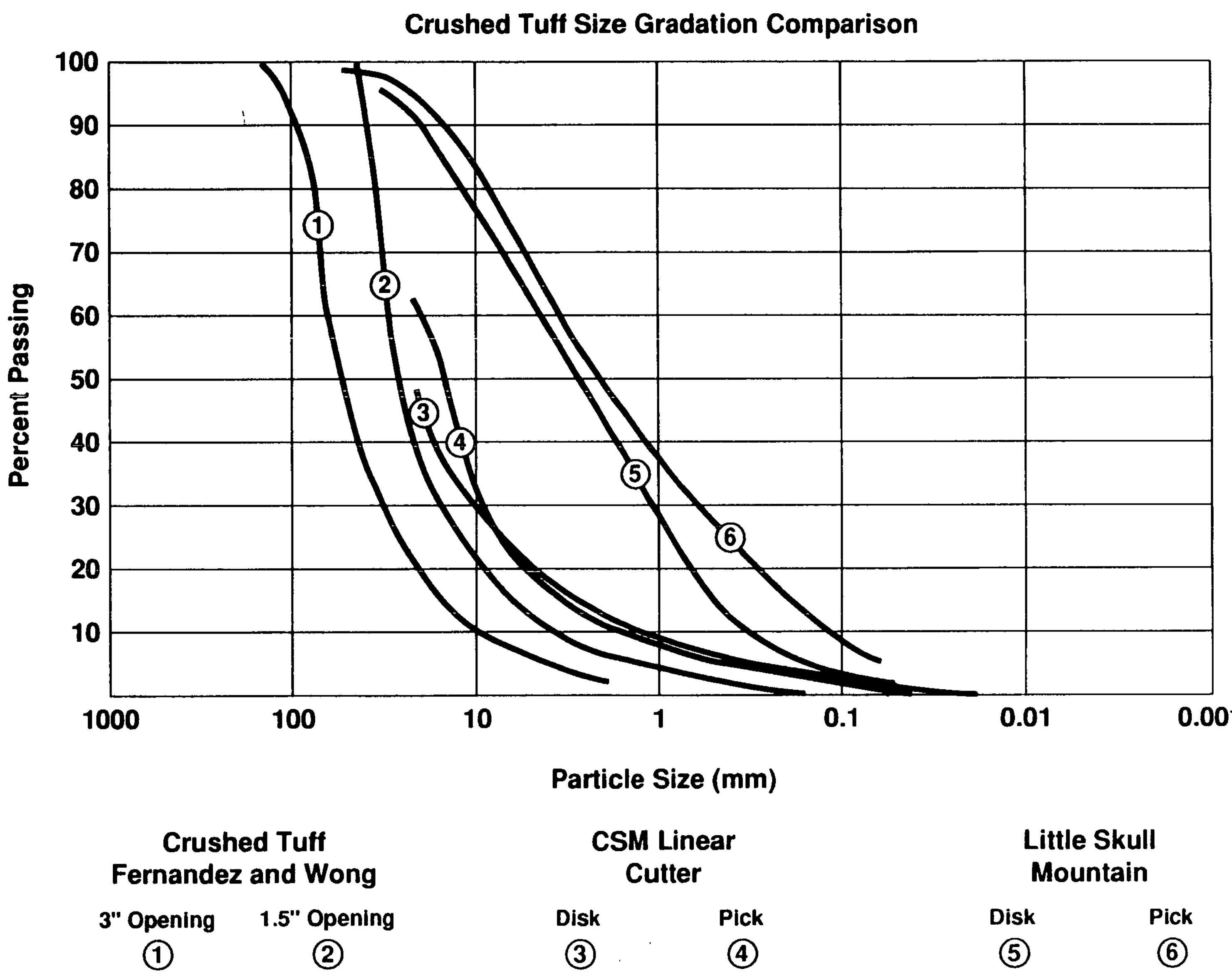


Refined Computation of Flow

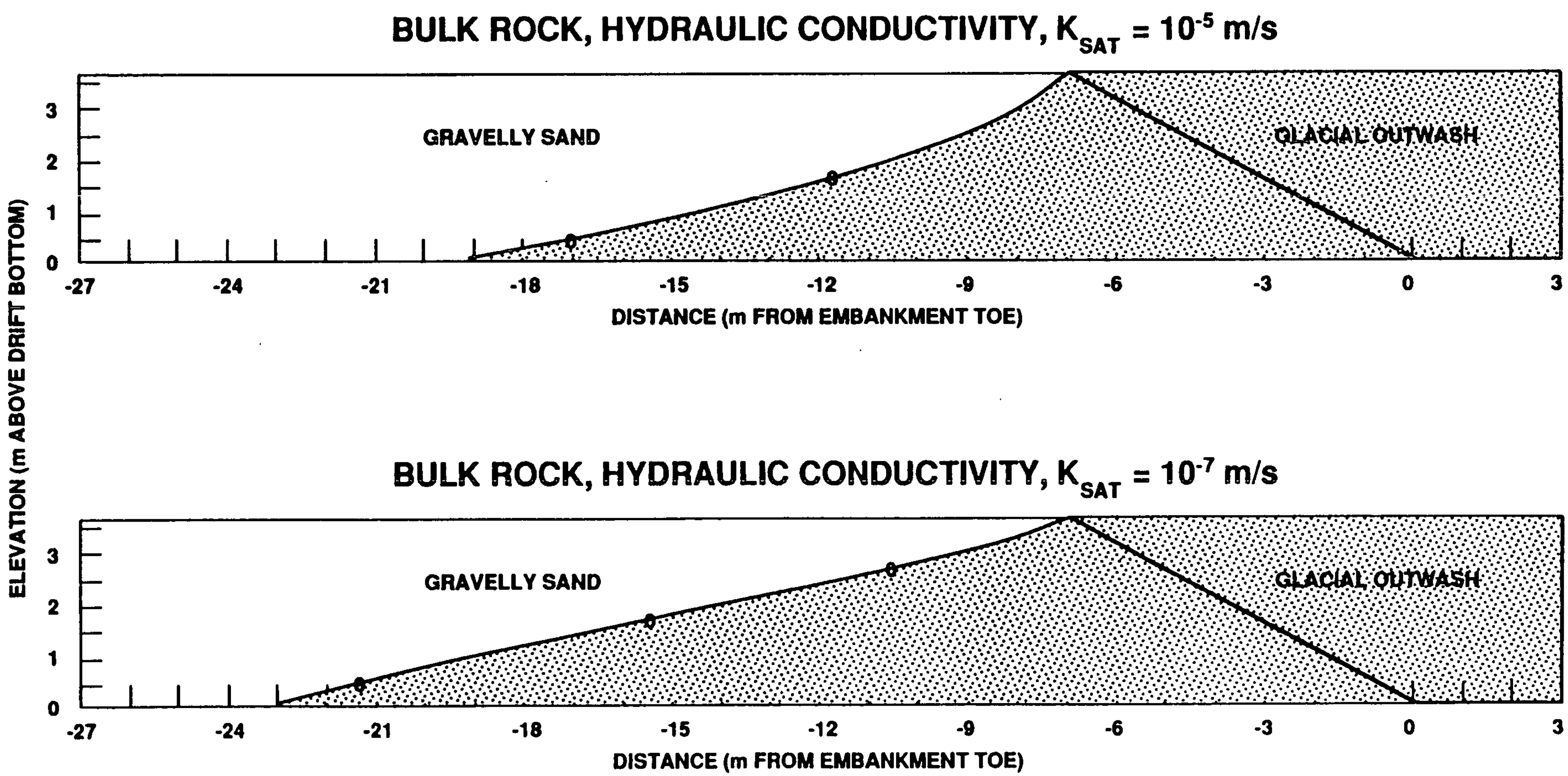
Drift Flow Model



Gradation of Crushed and Mined Tuff



Effect of Material Contrast on Drift Flow



Refined Computation of Flow Results and Conclusions

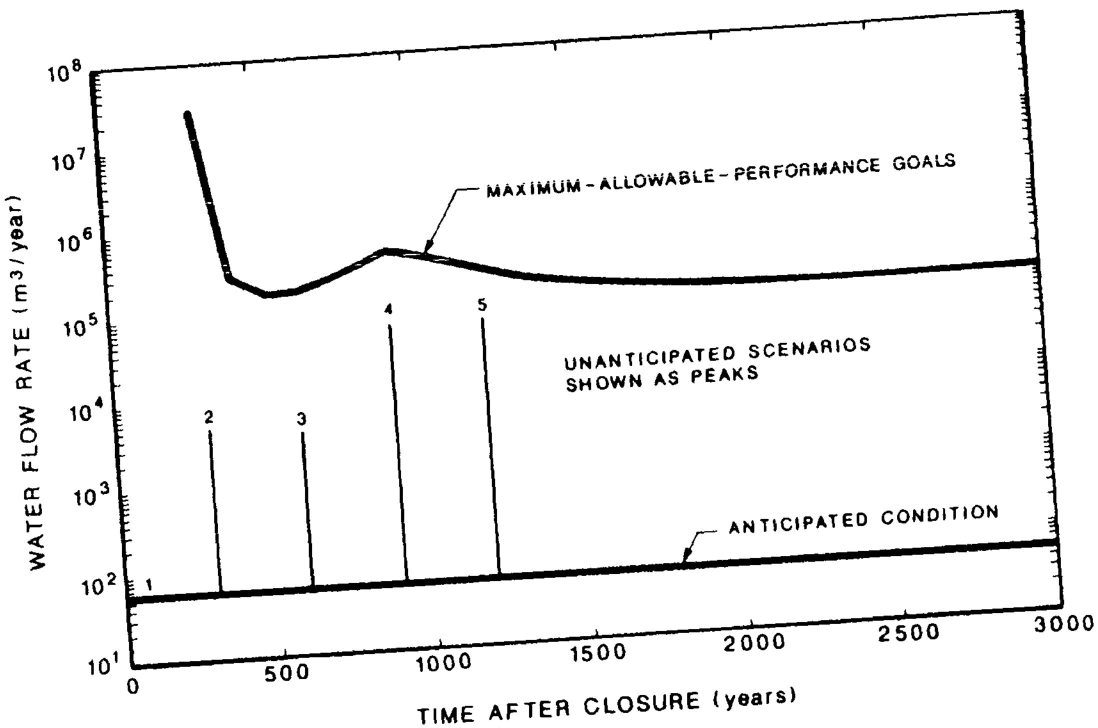
Fracture Flow Into Shafts

- **Shaft inflow through fractures 0 - 50 m^3/PMF (no buffering, i.e., direct water contact to fracture network)**
- **Extent of zone of influence is potentially limited even for a PMF**
- **Locating shafts out of alluvial zones is very effective in reducing water flow into shafts**
- **Layered soils (capillary barrier) may be very effective in reducing flow into shaft**

Drift Flow

- **Lateral flow in drifts can be controlled by material change along flow path**

Comparison of Goals and Flows



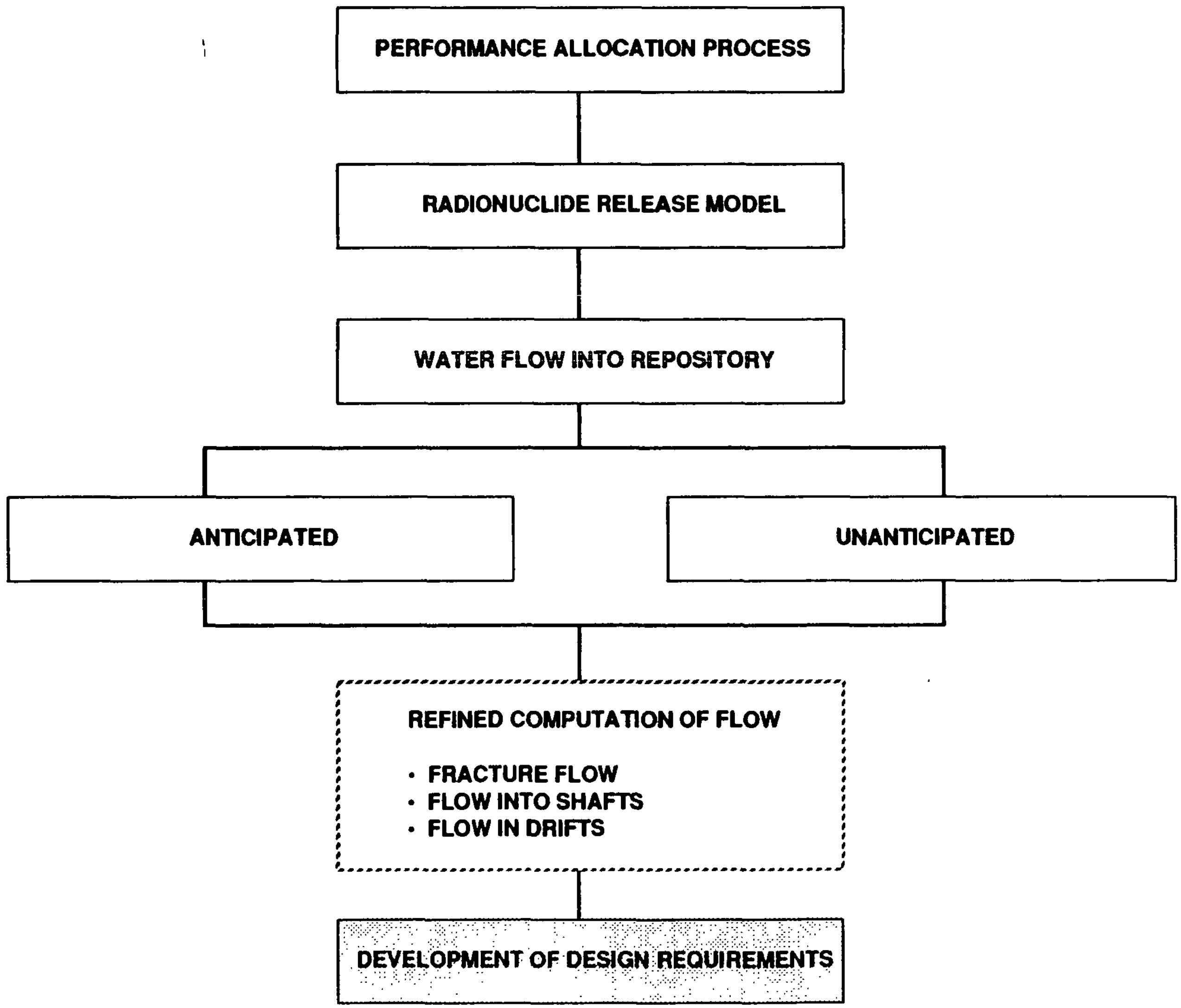
Condition

1. Anticipated
2. Unanticipated
   - Climatic change 1 mm/yr
3. Unanticipated
   - 500 year flood
4. Unanticipated
   - PMF flood
5. Unanticipated
   - Condition 2 and 4

Conclusions

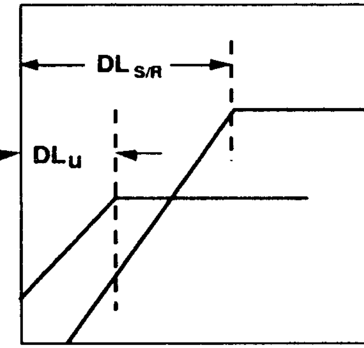
- Nominal sealing is only needed for anticipated conditions
- Sealing measures are proposed to provide a greater assurance that performance goals can be met

Scope of Presentation



Design Goals For Sealing Option

Design Life



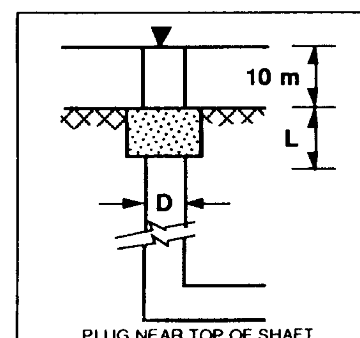
- 0 to 500 years--underground facility seals
- 0 to 1,000 years--shaft/ramp seals
- Progressive failure

Design Goals

$$DG_a(t_o) = \frac{S_m(t_o)}{x_a}$$

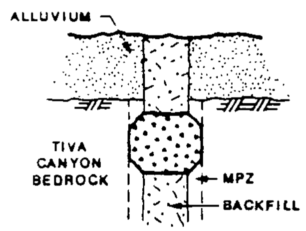
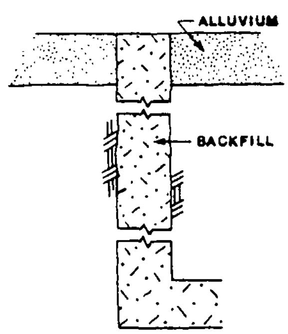
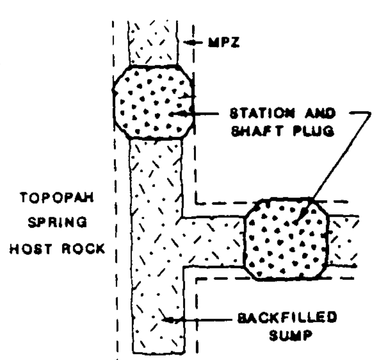
- Include storage capacity
  10,000 m^3 shaft/ramp system
  0 m^3 underground system
- Establish number of similar sealing components

Design Requirements

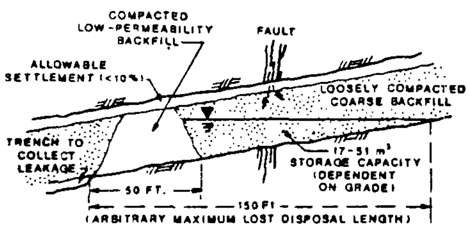
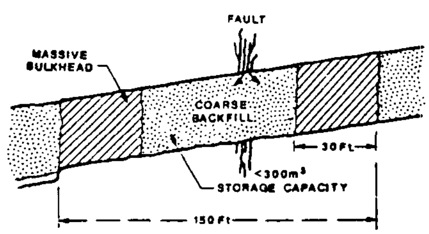
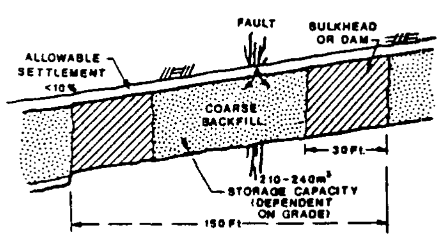


- Establish flow model
- Fully saturated above seal
- Develop design chart

Shaft/Ramp Component Design Goals and Requirements

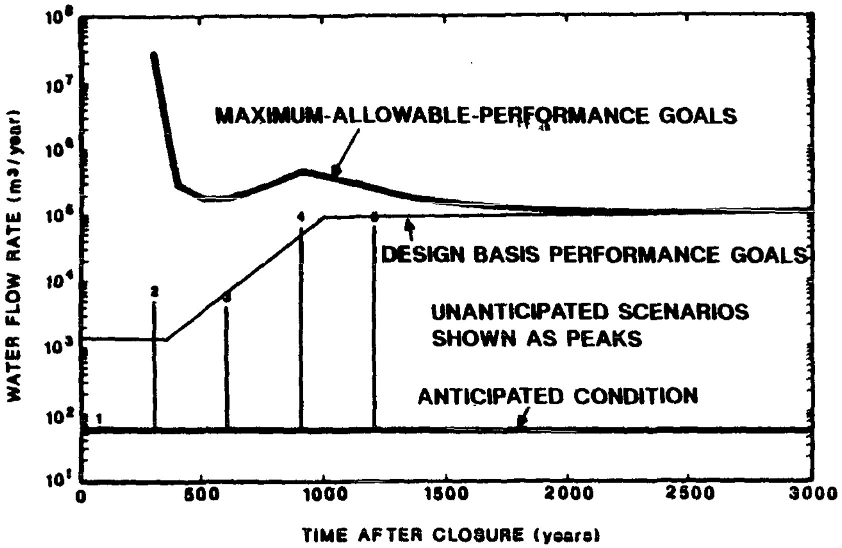
DESIGN OPTIONS	DESIGN GOALS	DESIGN REQUIREMENTS
 ANCHOR TO BEDROCK PLUG	• 1700 m^3/yr from 0 to 500 yr and 23,000 m^3/yr at end of sealing period (1,000 yrs)	• Effective hydraulic conductivity, 10^{-5} to 10^{-4} cm/s
	• Reduce potential for water and air flow	• Saturated hydraulic conductivity $\leq 10^{-2}$ cm/s
	• 1000 m^3/yr from 0 to 500 yrs and 14,000 m^3/yr at end of sealing period (1,000 yrs)	• Effective hydraulic conductivity 10^{-6} to 10^{-5} cm/s

Drift Component Design Goals and Requirements

DESIGN OPTIONS	DESIGN GOALS	DESIGN REQUIREMENTS
 (A) SINGLE DAM OR SINGLE BULKHEAD WITH SETTLEMENT	• 47 m^3/yr, 0 to 300 yrs and 220 m^3/yr to end of sealing period (500 yrs)	• Effective hydraulic conductivity, 10^{-5} to 10^{-4} cm/s
 (B) DOUBLE BULKHEAD (NO SETTLEMENT)	• 24 m^3/yr/ bulkhead, 0 to 300 yr and 110 m^3/yr/ bulkhead at end of sealing period (500 yrs)	• Effect hydraulic conductivity, 10^{-8} to 10^{-7} cm/s
 (C) DOUBLE DAM OR DOUBLE BULKHEAD WITH SETTLEMENT	• 24 m^3/yr/ bulkhead 0 to 300 yrs and 110 m^3/yr at end of sealing period (500 yrs)	• Effective hydraulic conductivity 10^{-5} to 10^{-4} cm/s

Results/Conclusions

- Design goals conservative



- One subsystem considered
- Performance goals reduced
- All water contacts waste
- Flow model--fully saturated
- Unanticipated flow--design basis
- Actual flow lower than design

- Design goals iterative
  - Reevaluate based on
    - Total system performance analysis
    - New baseline repository configuration