

An Approach to Risk Assessment at Contaminated Sites Characterized by Fractured Bedrock

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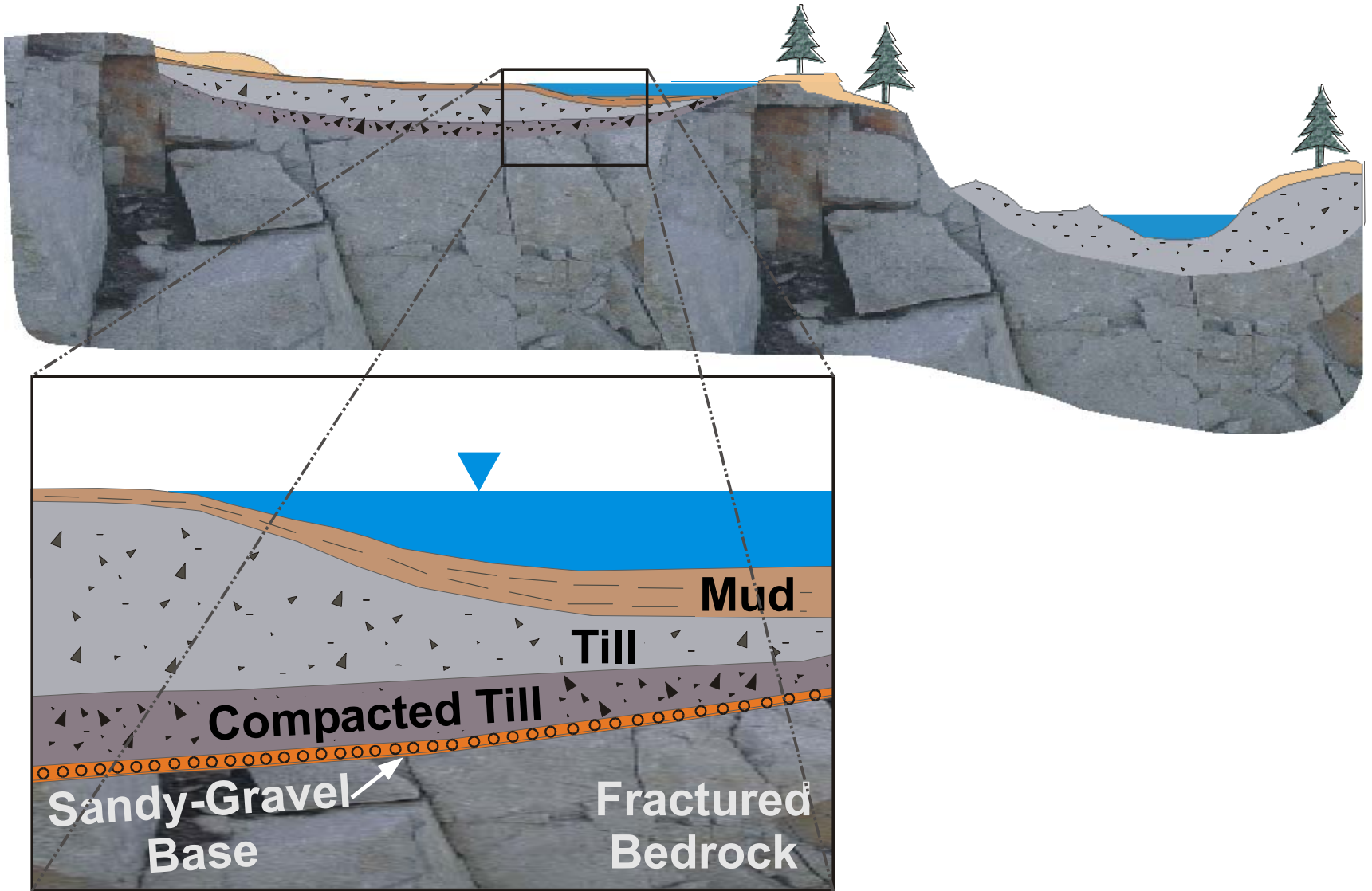
Background

- Thin overburden over fractured bedrock is common in Atlantic Canada
 - Glacial till cover, 1 to 3 m thick
 - Underlying fractured sedimentary, igneous, and metamorphic bedrock
- Petroleum hydrocarbon contamination (PHC) is widespread
- Atlantic RBCA is a process developed specifically for Atlantic Canada
 - Version 2 recently released
 - Incorporates Canada-Wide Standard for PHC in Soil
 - Soil Descriptions are different

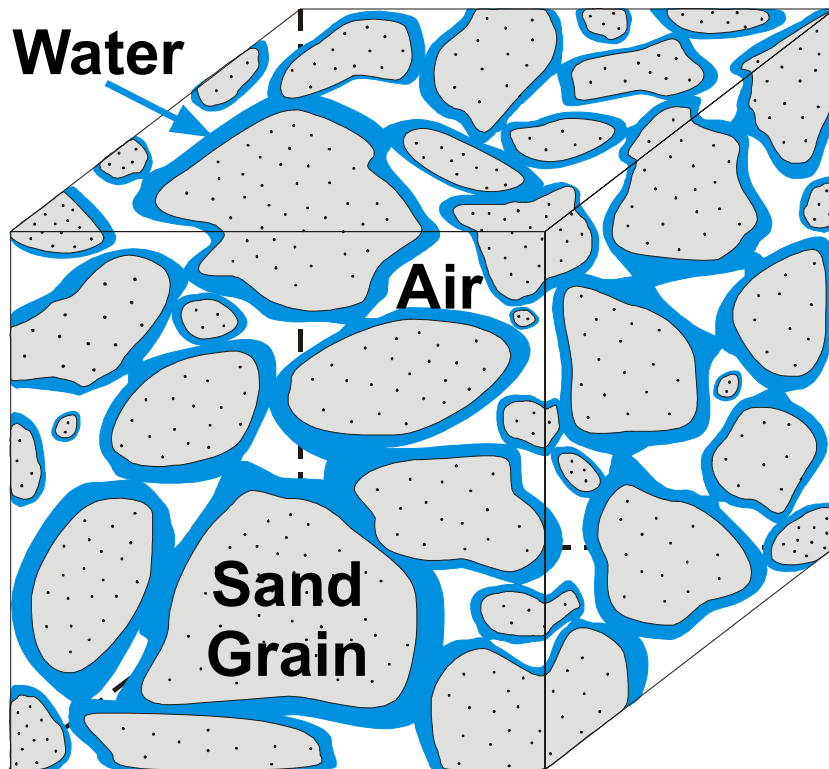
Background (continued)

- Atlantic RBCA specifies minimum requirements and reference guidelines for EAs of PHC sites and recognizes:
 - the need to describe surficial and bedrock geology (regional and local)
 - the need for a minimum of 3 boreholes/wells to determine groundwater flow direction
 - the need for bedrock monitoring wells to assess potable water sources
- Atlantic RBCA does not:
 - provide guidance on how to investigate sites characterized by fractured bedrock, and
 - does not permit an assessment of risk associated with PHC in fractured bedrock

Conceptual Model



Retention Capacity of Porous Media



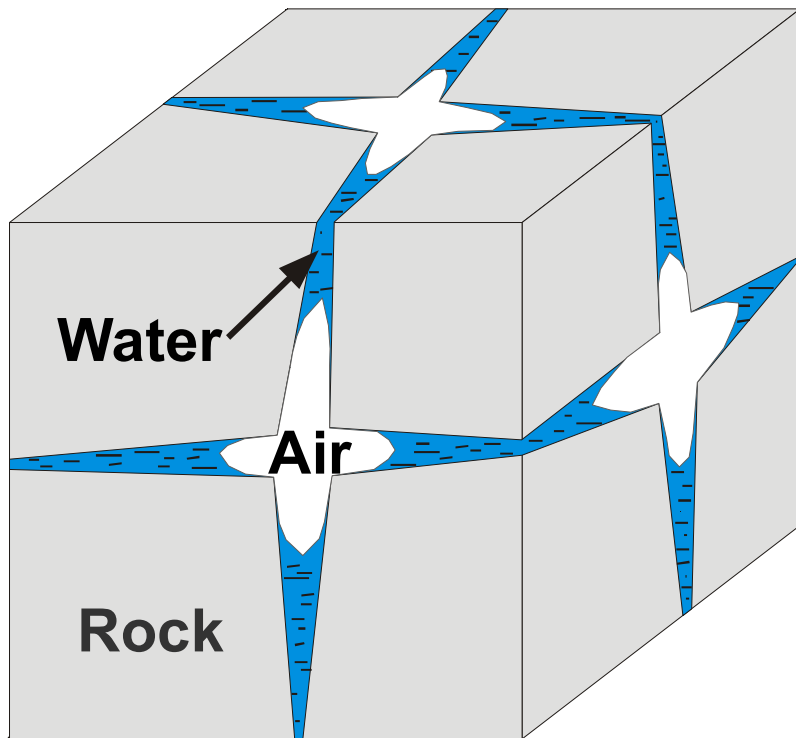
1m³ Block

$$n = 25\% = S_r + S_y$$

$$n = 250 \text{ litres}$$

$$= 50 \text{ L} + 200 \text{ L}$$

Retention Capacity of Fractured Rock



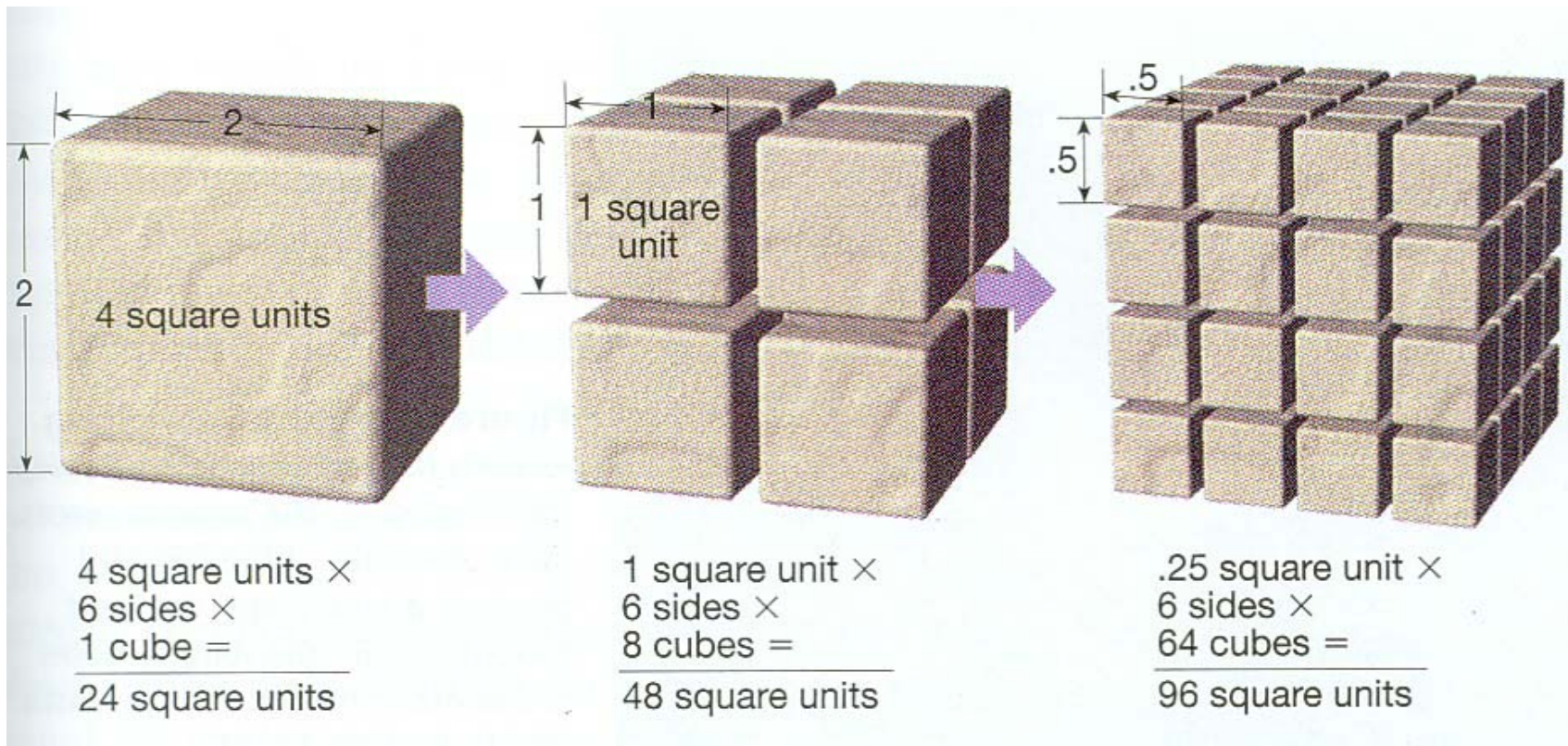
3 Orthogonal Fractures
– 1 m spacing

1 mm wide apertures
 $n = 0.1\%$

$$n = 1 \text{ litre} = S_r + S_y$$

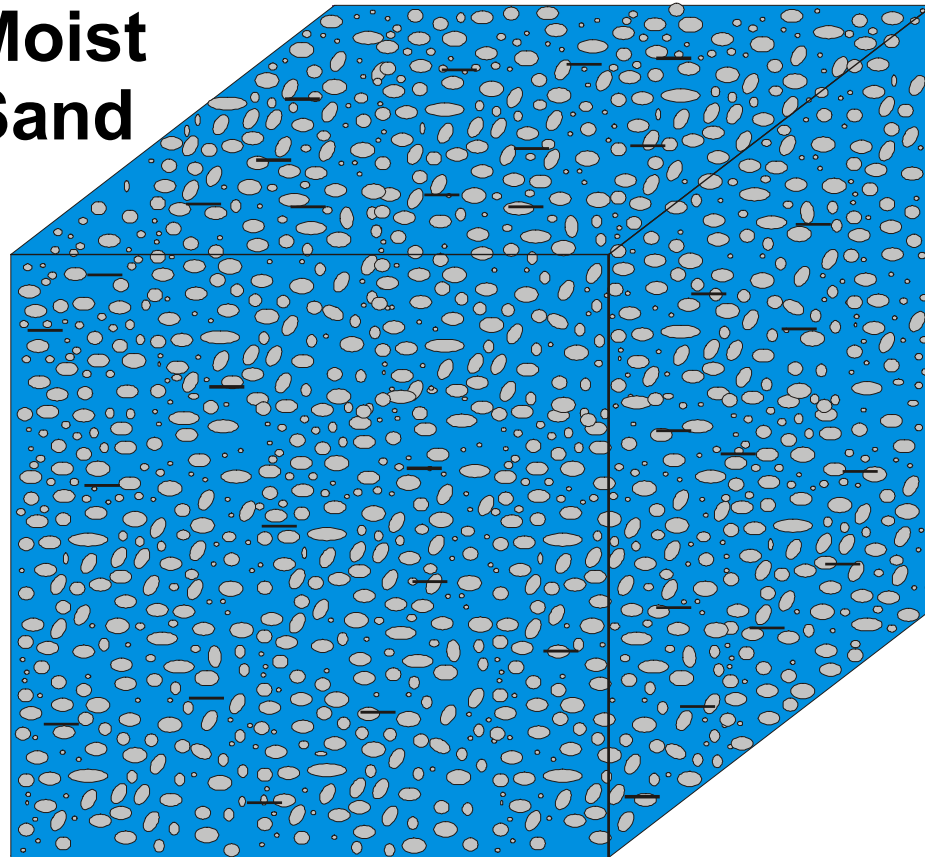
$$1 \text{ litre} = 0.75 \text{ L} + 0.25 \text{ L}$$

Surface Area of Fractured Rock



Surface Area of Porous Media

**Moist
Sand**



Volumes of Impacted Material From Typical Oil Spill (250 Litres)

POROUS MEDIA

**1 to 10 m³ of Soil Potentially
Impacted**

FRACTURED BEDROCK

**250 to 500 m³ of Fractured Rock
Potentially Impacted**

Problems with Typical Site Characterization Approach

- Vertical Boreholes/Wells used in 3D Fracture Network
- Borehole Patterns not Related to Local Fracture Geometry and Preferred Directions of Flow
- Well Testing / Sampling Programme does not Investigate/Determine the Properties of Discrete Fractures

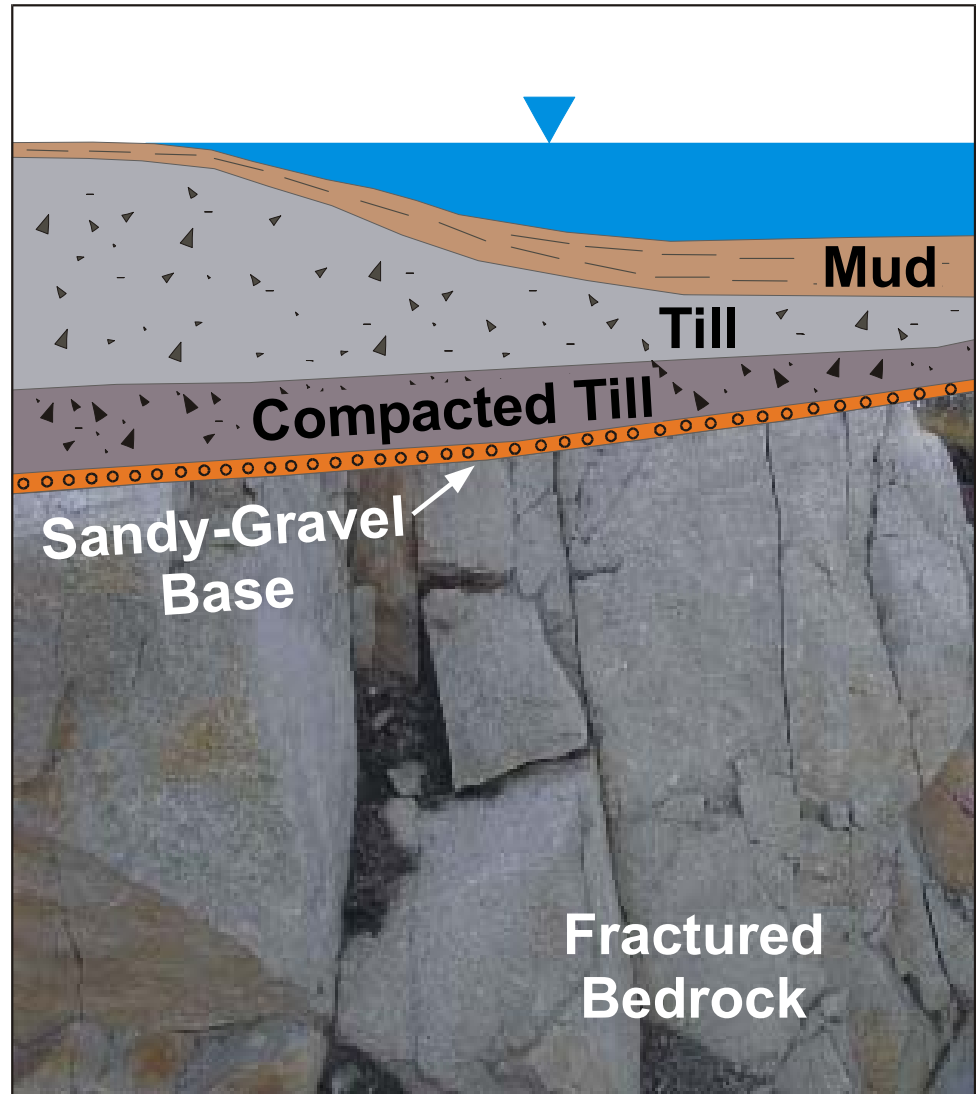
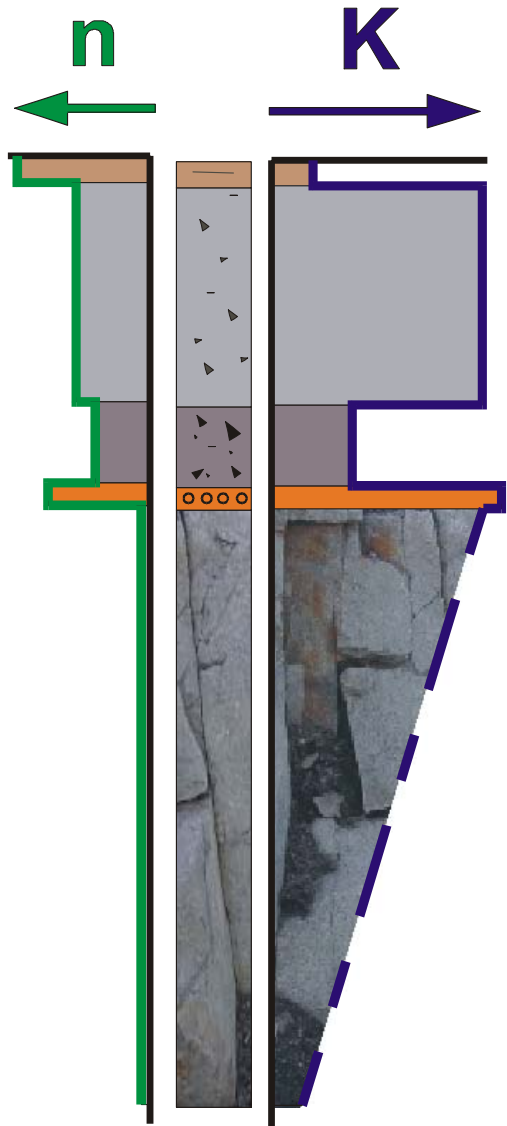
Vertical Borehole



Proposed Approach

- Develop the Conceptual Model
- Assess Fracture Geometry
- Design borehole program to be consistent with 3D fracture network
- Drill inclined boreholes
- Test/sample discrete fractures or narrow fracture zones
- Interpret data and assess risk

Conceptual Model



Assess Fracture Geometry

- Scanline Mapping
- Local/Regional Geological Maps
- Local Fracture Geometry Mimics Large Scale Structural Features

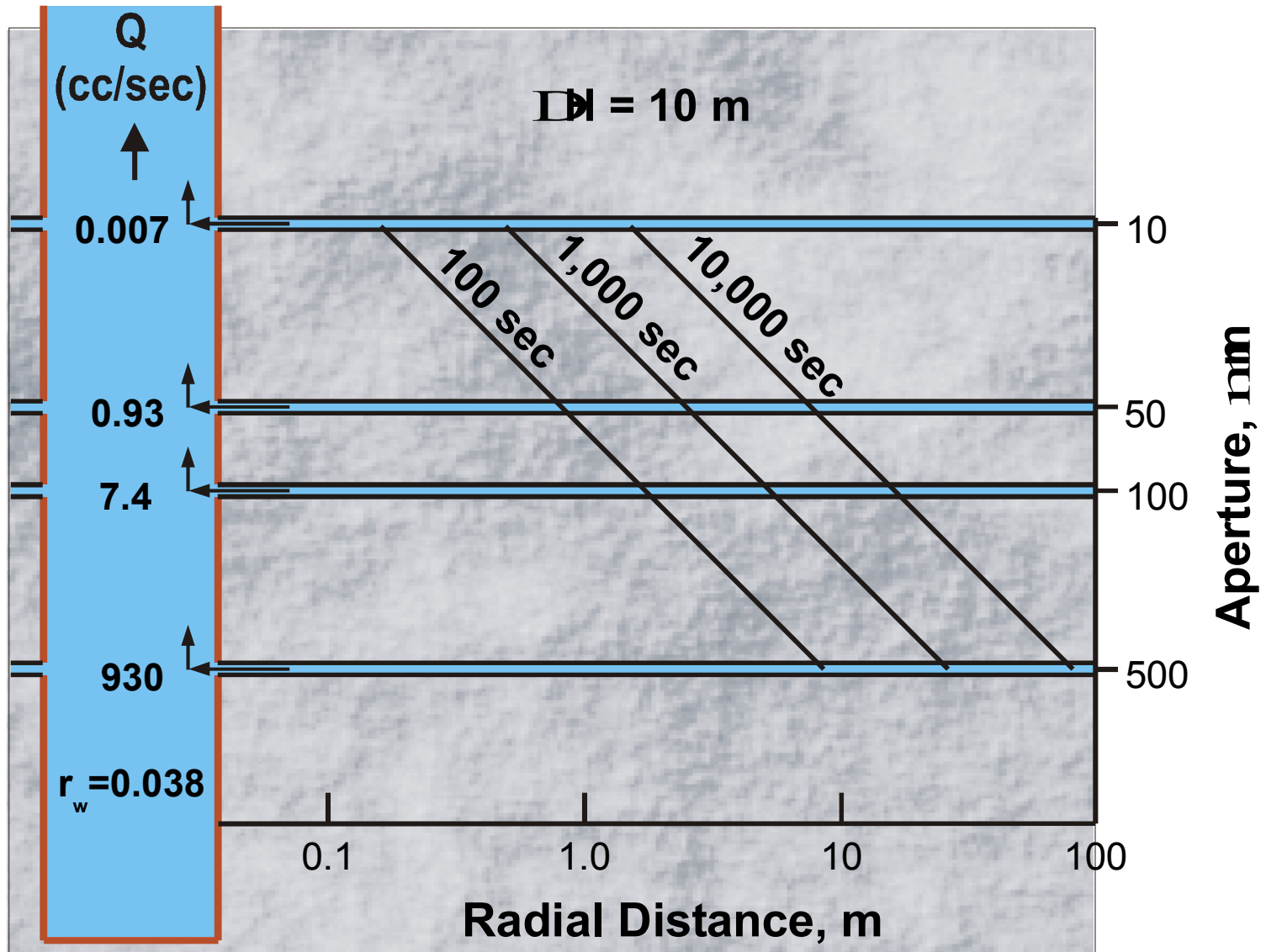
Design and Conduct Borehole Program

- Exploratory Inclined Borehole to Confirm/Assess Fracture Geometry
- Drill Additional Boreholes (Vertical or Inclined as Needed), Examine Rock Core
- Borehole TV Camera Work
- Permeability Testing Using Modified Double-Packer System
- Installation of Multi-Level Piezometers/Nested Wells, and Sampling

Inclined Borehole



Interpret Data and Assess Risk



Conclusions

- Risks Associated with PHC at Sites Characterized by Thin Overburden over Fractured Bedrock Needs to be Addressed. The Approach Should Include:
 - Development of the Site Conceptual Model
 - Initial Assessment of Fracture Geometry
 - Design and Completion of an Intrusive Testing Program that Respects the 3D Fracture Network
 - Proper Data Interpretation

Conclusions (continued)

- Need to Incorporate Porosity, Permeability and Velocities of Discrete Fractures and/or Fracture Zones into the Fate and Transport Analysis
- The Minimum Requirements and Guidelines for EAs at PHC sites under Atlantic RBCA Should be Amended

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