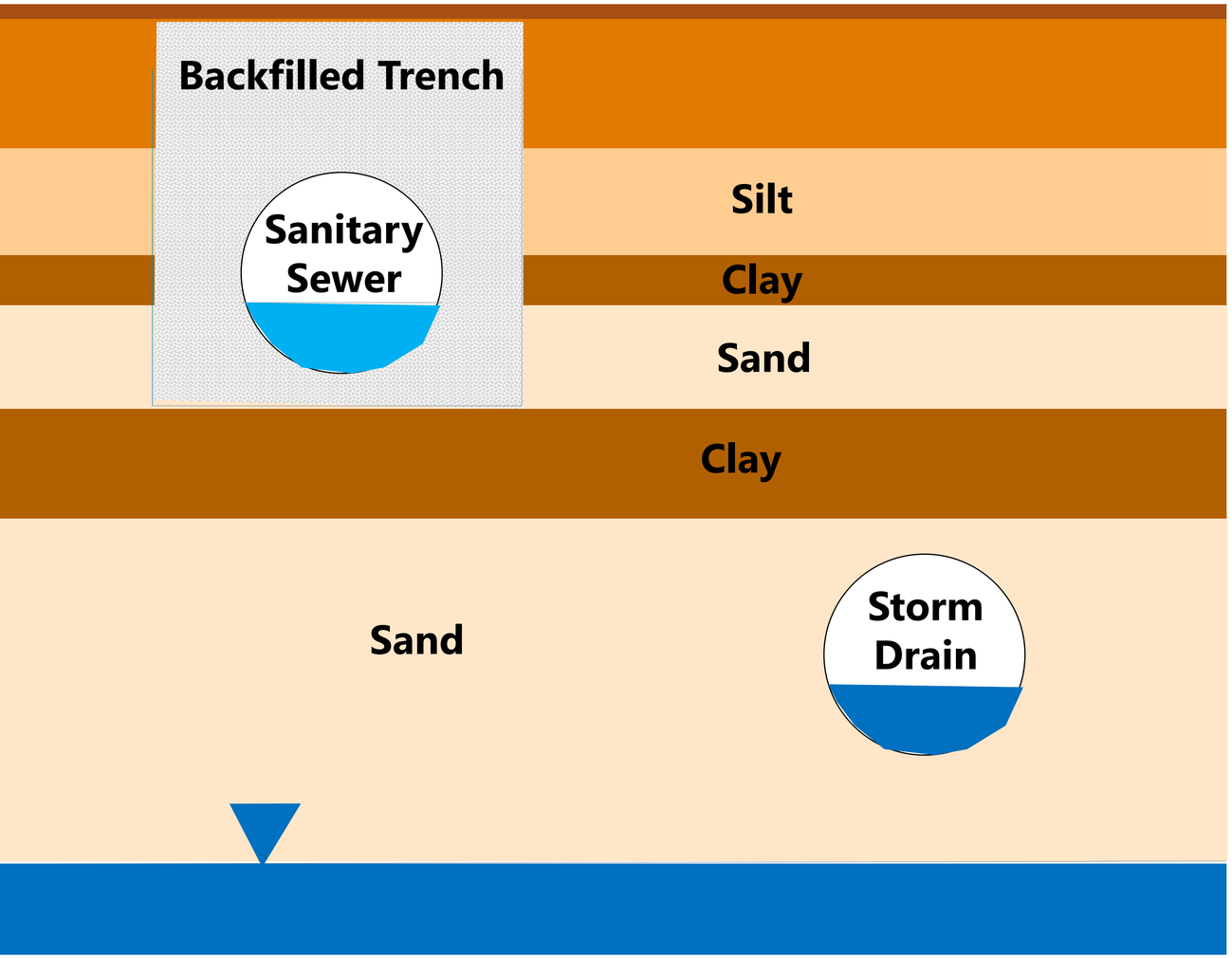
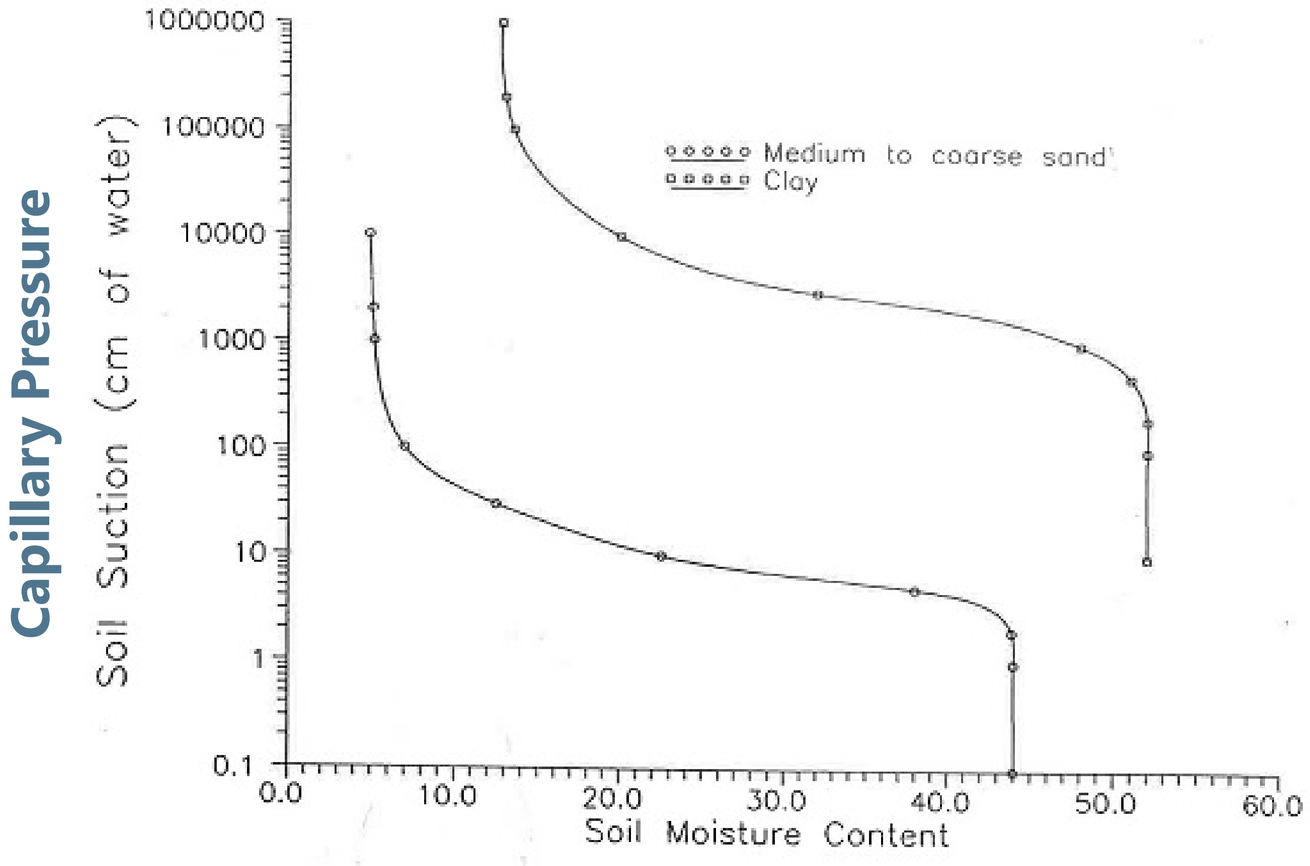
Exfiltration



- Movement of fluid dictated by hydraulic head (pressure + elevation potentials)
- In unsaturated soils, moisture content plays significant role in flow
- Moisture content = capillary pressure
  - Defines capillary fringe
  - Gravel + Sand = low cap pressure, low fringe
  - Silt + Clay = high cap pressure, high fringe

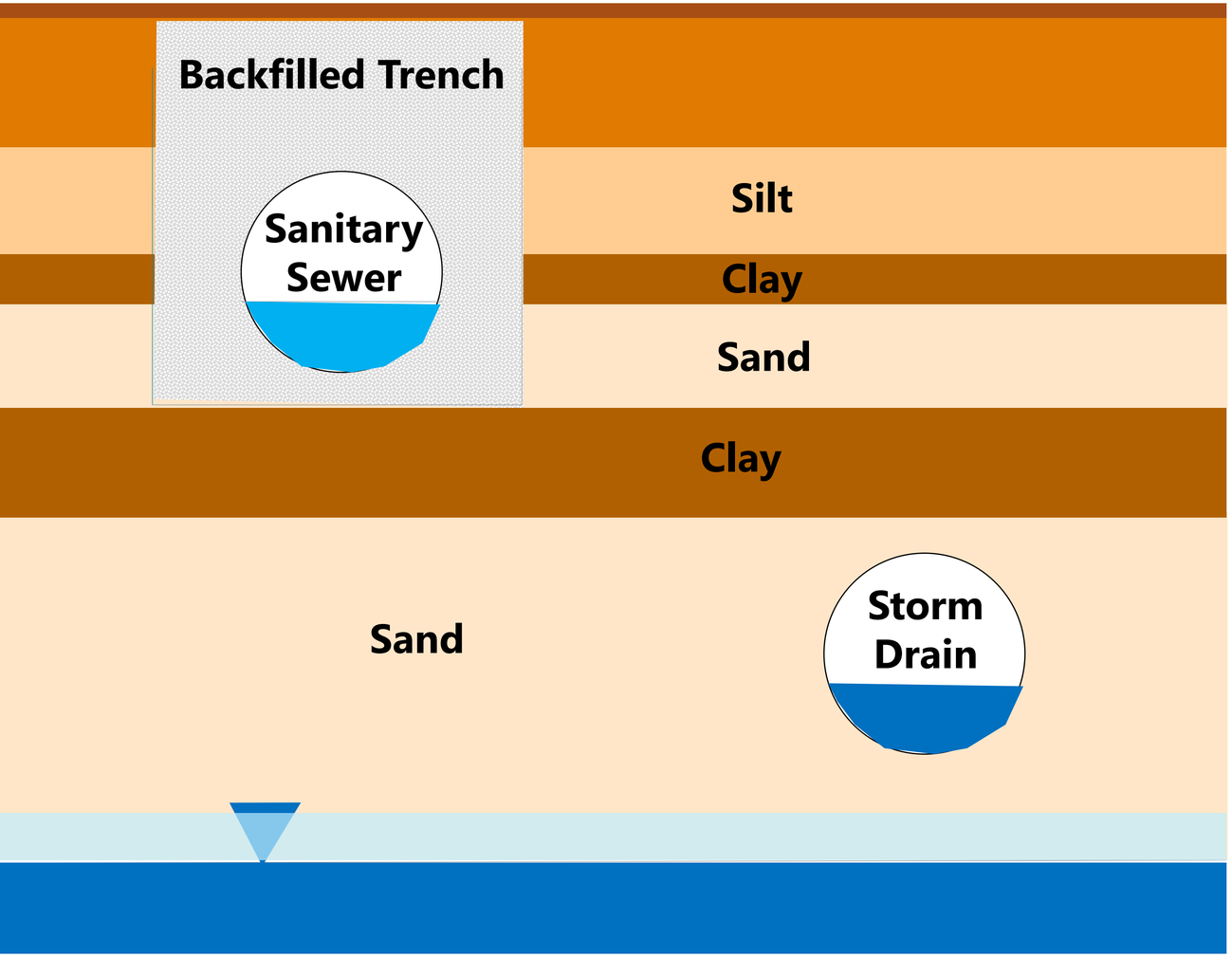
Exfiltration



Capillary Pressure vs. Moisture Content

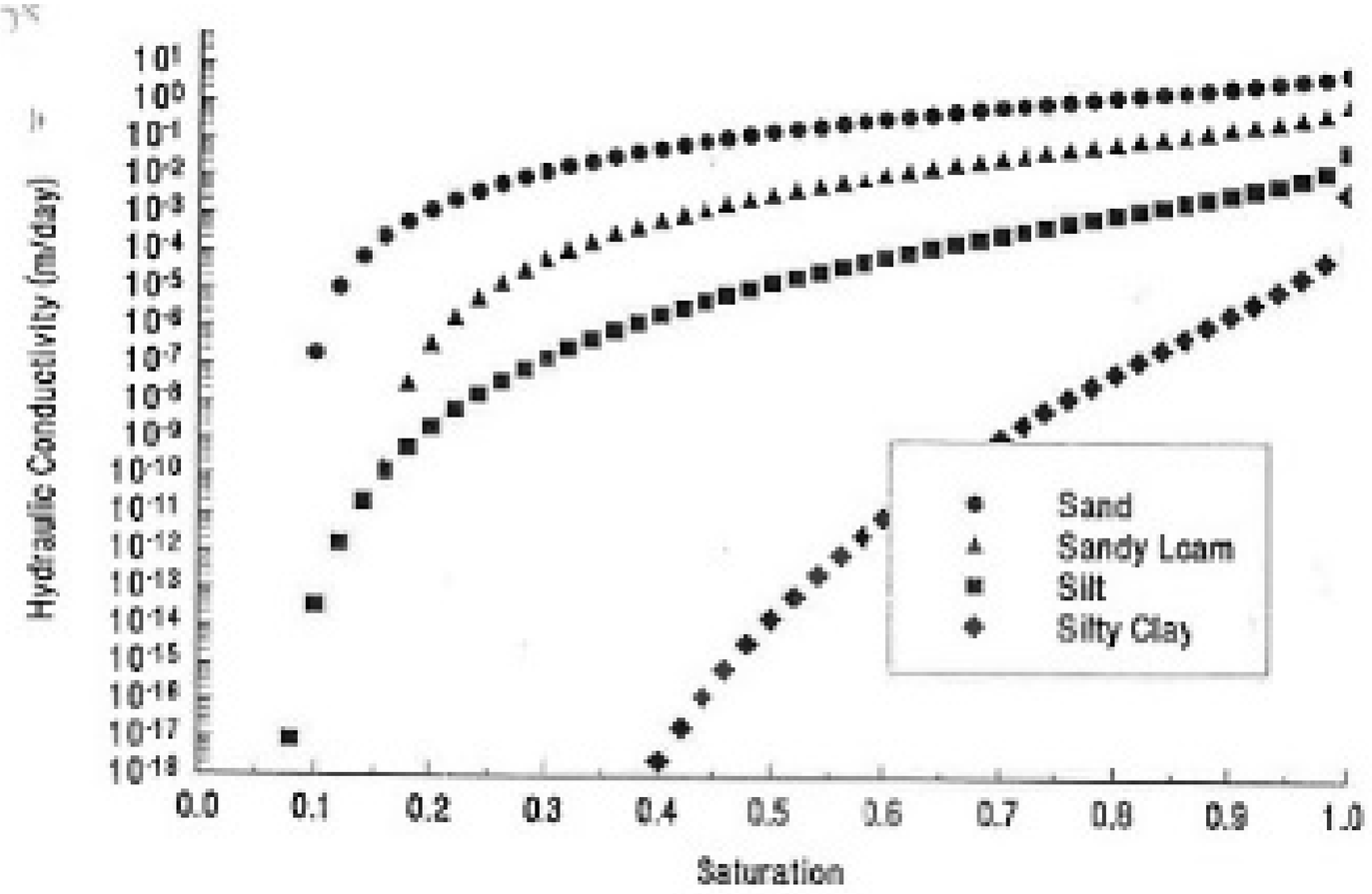
- Sand
  - Lower fringe (1 to 5 cm)
  - Lower residual moisture content (5-7%)
- Clay
  - Higher fringe (300 to 1000 cm)
  - Higher residual moisture content (12-14%)

Exfiltration



- Darcy's Law: $Q=KAI$
  - Q = volumetric flow rate (L^3/T)
  - K = hydraulic conductivity (L/T)
  - A = Area of flow (L^2)
  - I = hydraulic gradient
- K is characteristic of soil type and ability to transmit water
  - Higher K = gravels and sands
  - Lower K = silts and clays
  - Especially true in unsaturated soils

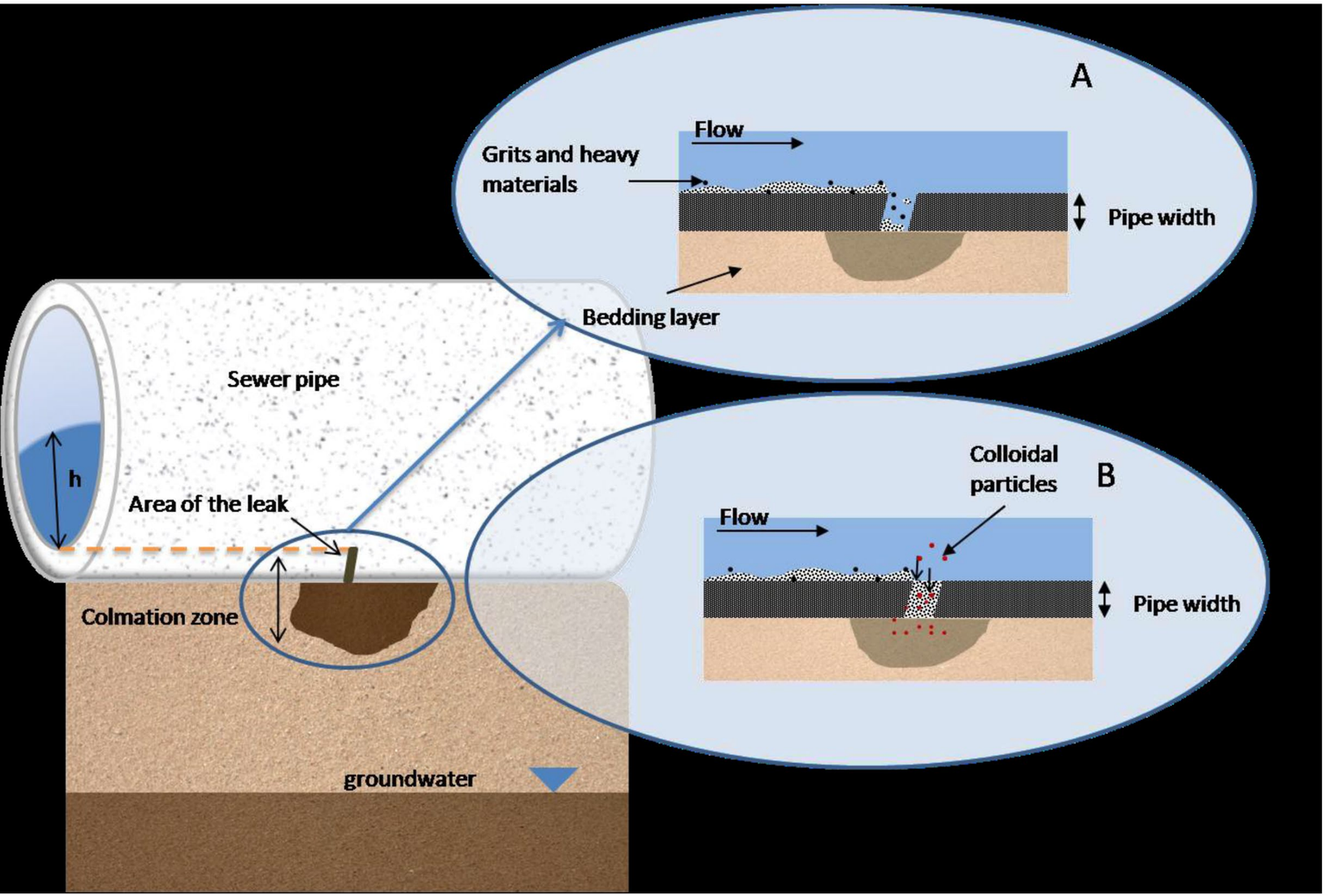
Exfiltration



K vs. Soil Saturation

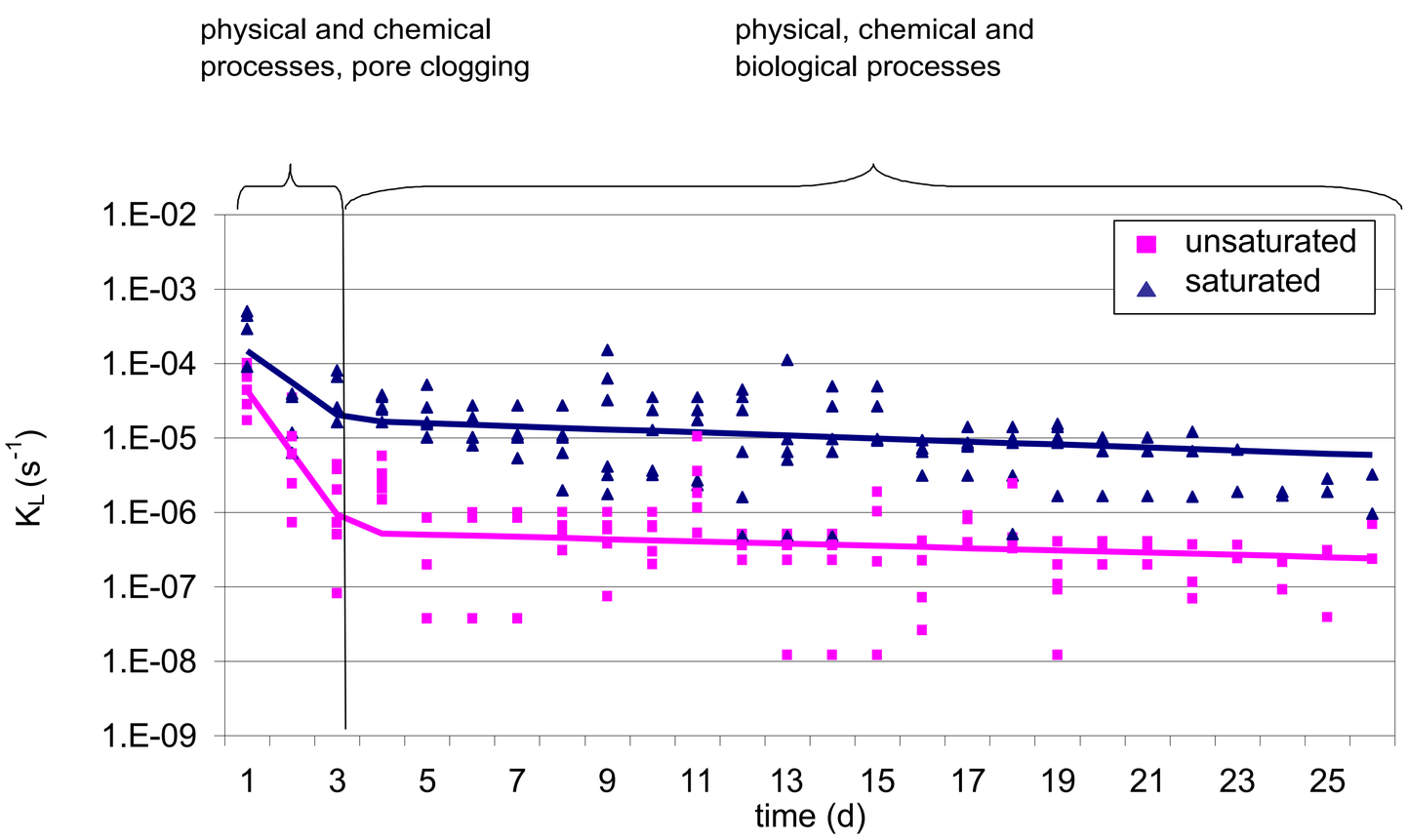
- **At 100% saturation,**
  - K_{sand} = 10 m/day
  - K_{clay} = 10^{-3} m/day
  - Δ = 3 orders of magnitude
- **At 50% saturation,**
  - K_{sand} = 0.1 m/day
  - K_{clay} = 10^{-14} m/day
  - Δ = 13 orders of magnitude!

Exfiltration



- Colmation Layer (i.e., clogging layer)
- Accumulation of suspended solids and biomass
  - 1 to 5 cm thick
  - Reduces K and porosity
  - Exfiltration rate decreases
  - Leakage factor defined as
  - $K_L = K_c/Z_b$
    - K_c = conductivity of colmation layer
    - Z_b = thickness of colmation layer

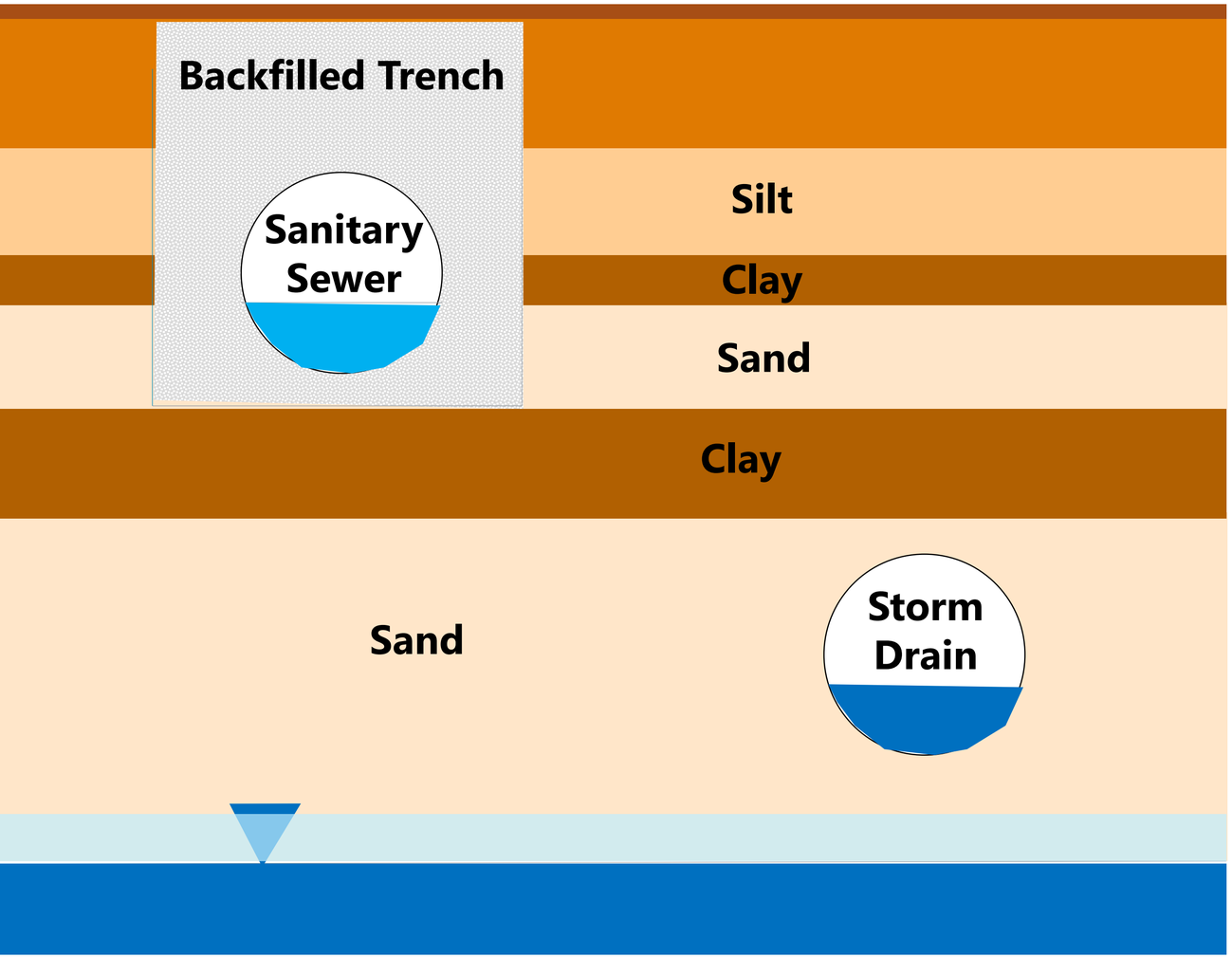
Exfiltration



Exfiltration and formation of colmation layer

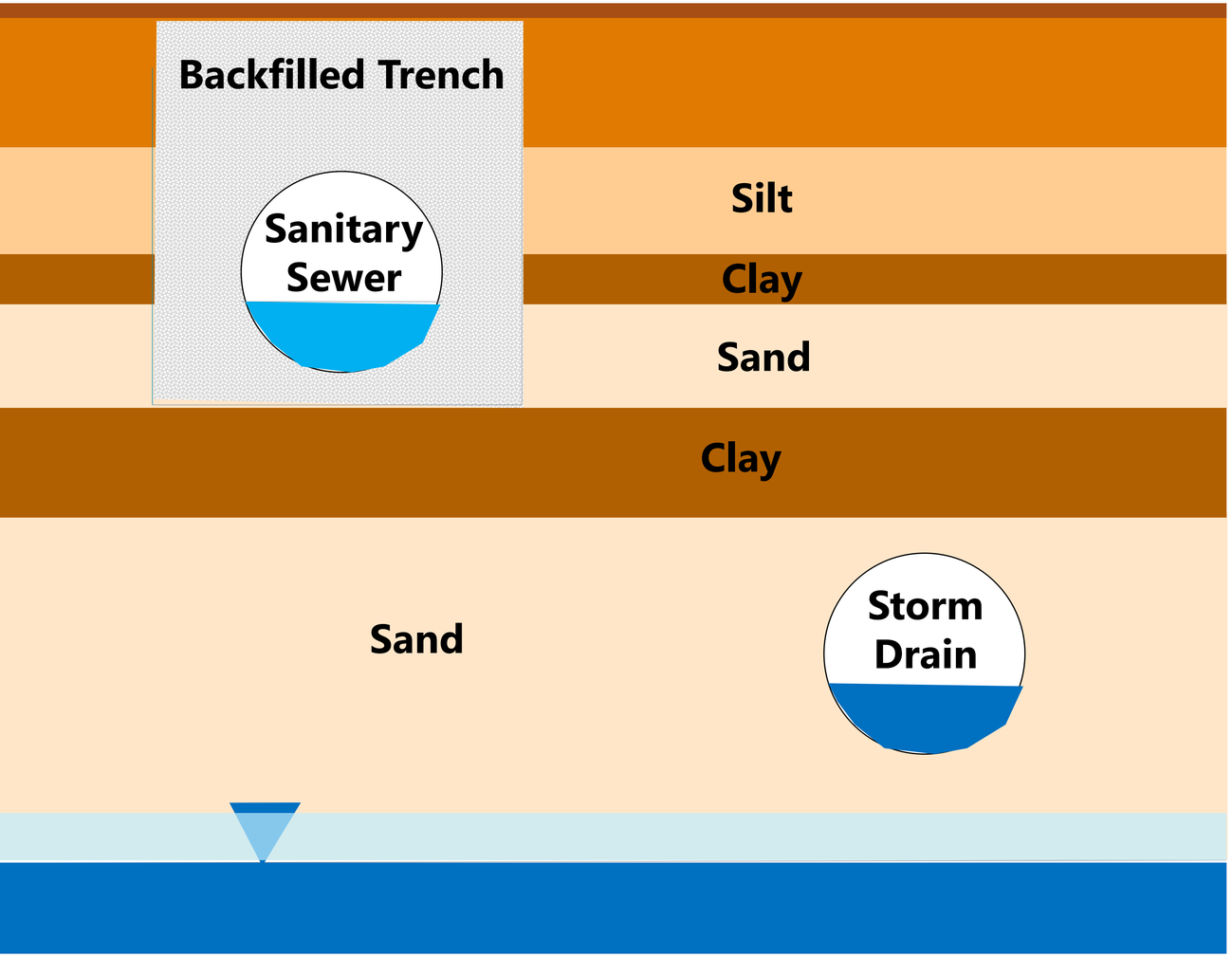
- Study related K_L to capillary pressure and colmation layer
- Initial leak
  - Capillary pressure induces higher gradient and leakage rate
  - As colmation layer develops, decrease in K_L
    - 1 to 2 orders magnitude in 3 days

Infiltration



- What about infiltration to storm drain?
- Exfiltration from sewer must travel to storm drain
  - driven by gradient (consistent?)
  - Preferential flow paths
  - Entry point at storm drain
    - Overcome hydrostatic and pore pressures at entry point

Summary



- Exfiltration a function of:
  - Soil type from backfilled trench (if present) to native formation(s)
  - Moisture contents
  - Formation of colmation layer
  - Hydraulic gradient
- What soil type is in the area of your pipeline?
  - USDA has an online resource:
  - https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm