



5. Relative permeability,  $k_r(S_w)$ .

6. Advective velocity,  $v_a$

7. Seismic profiling.

8. Distribution coefficient,  $k_d$ .

9. Effective solubility,  $S_e$ .

10. Minimum ganglion length,  $h_{min}$ .

## Question 2

The breakthrough curve of the chloride plume ( $Cl$  is a conservative tracer) at a compliance well, 2 km downstream of a landfill, is as shown. The aqueous chloride concentration in the landfill is 200 ppm, which acts as a constant concentration or fixed step source at the head of a one-dimensional flowfield.

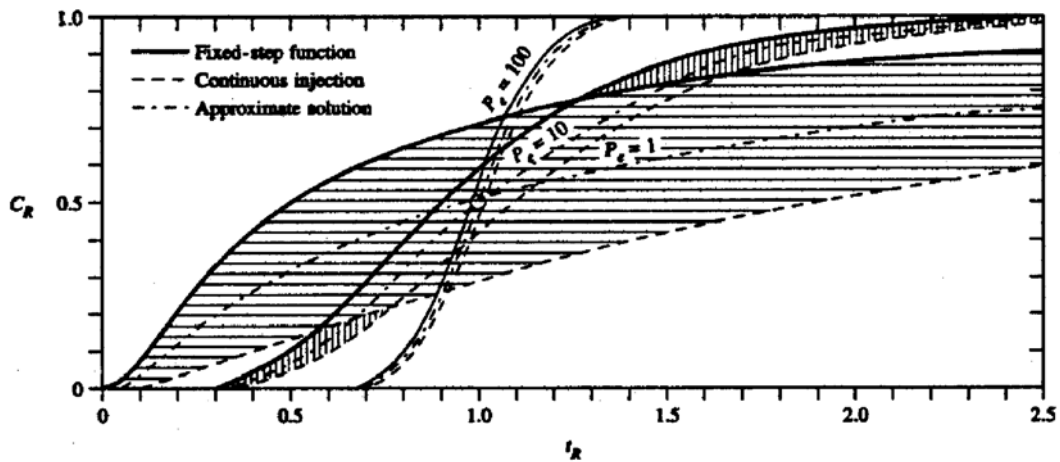
Use the attached chart, defining theoretical breakthrough curves, in terms of advective velocity,  $v$ , dispersion coefficient,  $D_L$ , distance to measuring point,  $L$ , and time since the commissioning of the

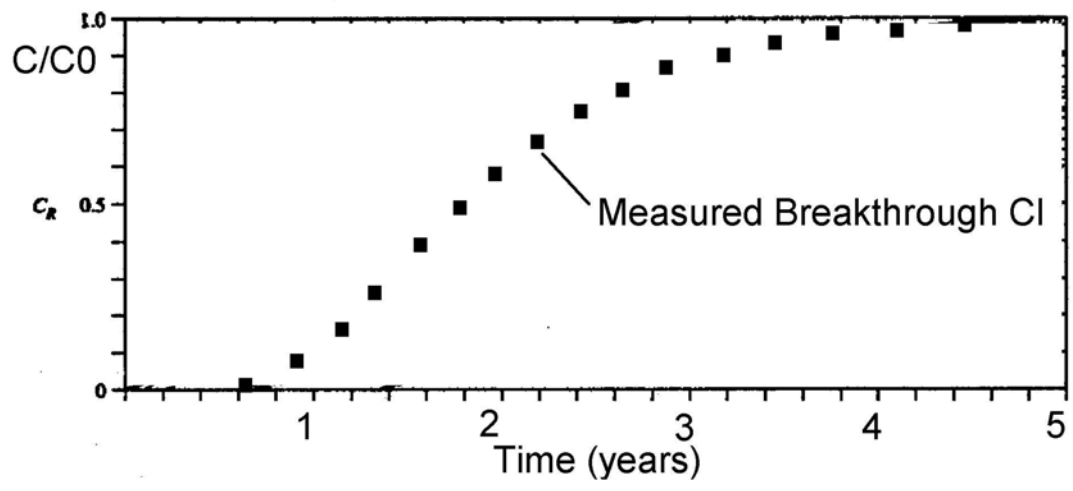
landfill,  $t$ , to determining the following  $\left[ P_e = \frac{v.L}{D_L}; \quad t_R = \frac{v.t}{L} \right]$

1. If  $Cl$  is a conservative tracer, determine the advective velocity of the flow field.
2. What is the longitudinal dispersion coefficient  $D_L$ , for  $Cl$  from the system.
3. If the effective diffusion coefficient of salt in water is  $10^{-9} \text{ m}^2/\text{s}$ , what is the longitudinal dispersion coefficient,  $\alpha_L$ .

4. If TCE is also moving through the aquifer, from the same source, that is retarded by a factor of 10 ( $R=10$ ), when will the breakthrough occur at the same compliance point, equal to 80% of its upstream concentration. Consider the same compliance point.

5. For a more mildly retarded species, PCE, present upstream at 500ppb breaks through at the compliance point at a concentration of 400ppb after 4.2 years. What is the retardation factor for PCE.





### Question 3

A spill of gasoline has occurred at a site where silty sands overlay thick shales with a weathered upper interface.

1. Describe an appropriate (direct) site investigation for this site to:
  - a. Evaluate stratigraphy and geology.
  - b. Determine the extent of NAPL (free product) and dissolved product contamination.
  - c. Determine the potential for offsite migration of the aqueous plume.

Use note form, if you wish, to itemize your choices and explain their relevance.

2. The site investigation indicates that sand overlies the fractured shale aquiclude. The upper 6m of the shale is highly weathered and fractured ( $k=10^{-2} \text{cm/s}$ ) and below that is tight. The water table is 2m below the ground surface and free product is present over an area of about  $100\text{m}^2$ .

Identify, and describe the operating principles of three remedial techniques that may be applied to this site. For each of these three applicable techniques, identify three factors that make the technique particularly applicable to the site. Use note form to answer if you wish.

