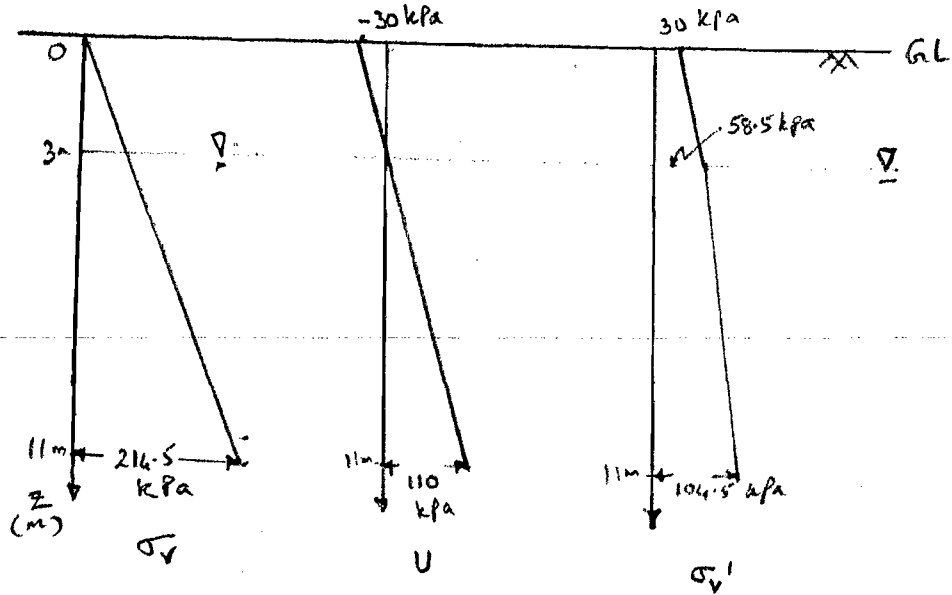
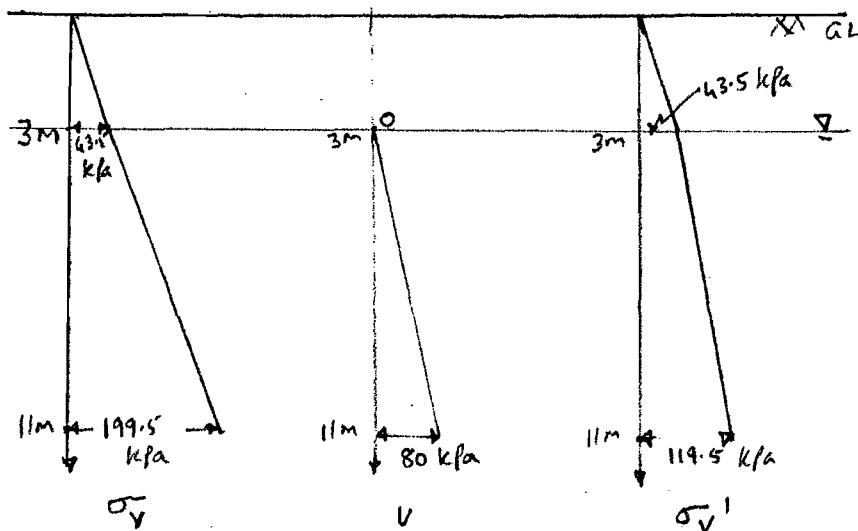


- 1 a) Unit weight of dry silty soil = 14.5 kN/m^3
 Unit weight of saturated silty soil = 19.5 kN/m^3

i) silty soil remains saturated above water table.

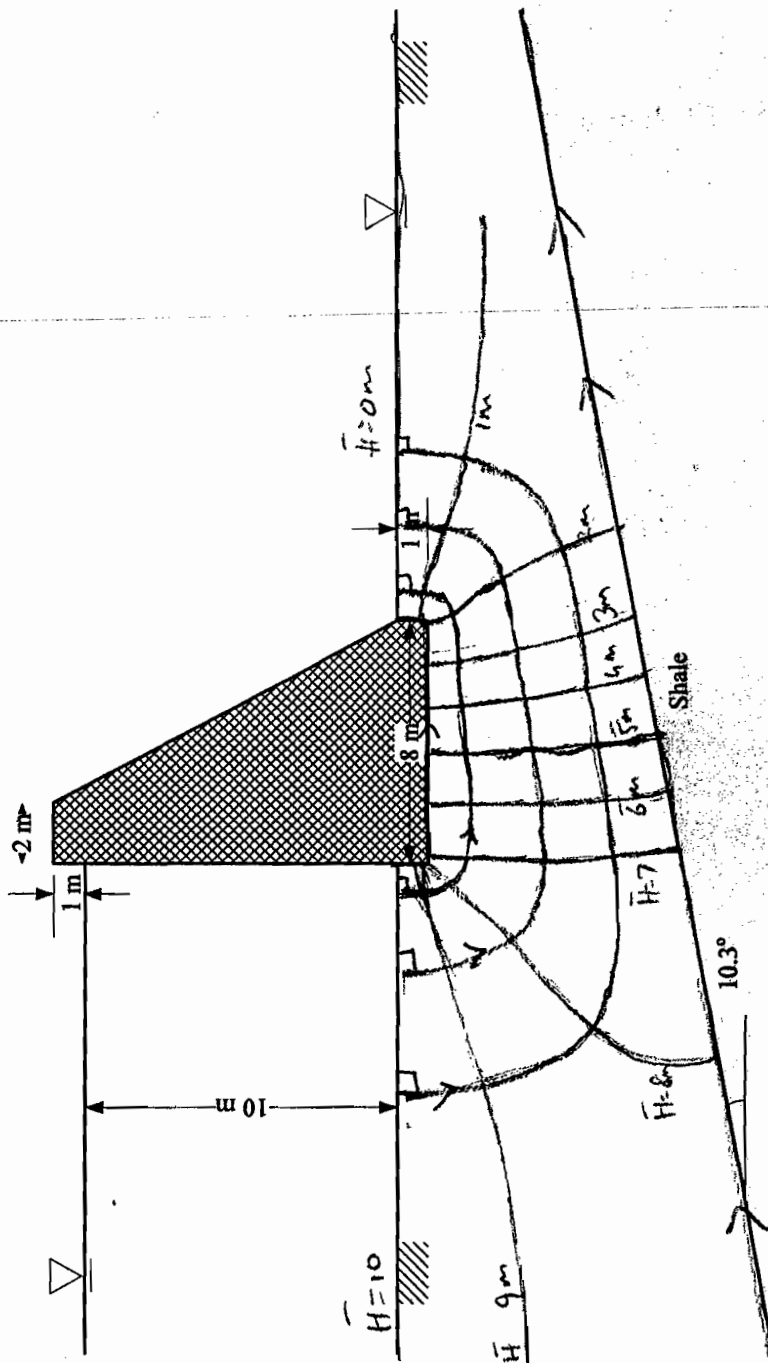


ii) silty soil is dry above water table

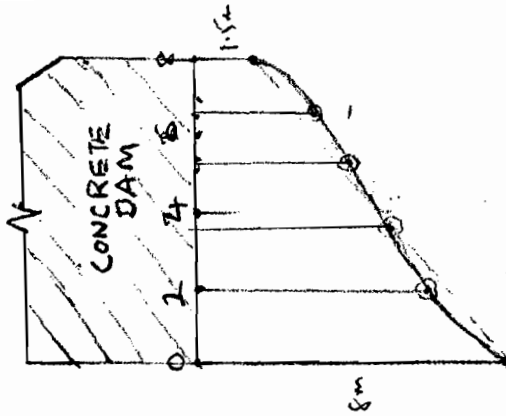


[20%]

1 b) i)



1 b) (ii)



UPLIFT
PRESSURE
DISTRIBUTION

[20%]

[20%]

$$1\ b\ ii) \quad Q = K \Delta H \frac{N_f}{N_h}$$

$$\Delta H = 10\ m ; \quad K = 3.2 \times 10^{-4}\ m/s$$

$$\text{From b i) } N_f = 3.5 \quad N_h = 10$$

$$\therefore Q = 3.2 \times 10^{-4} \times 10 \times \frac{3.5}{10} = 1.12 \times 10^{-3}\ m^3/s/m \quad [10\%]$$

b iii) Uplift pressure distribution is sketched on page 2. This indicates a non-linear variation of uplift pressure. As we are trying to integrate the area underneath this curve, we can approximate this as a linear variation.

$$\therefore \text{Uplift force} = \gamma_w \left[8 \times 1.5 + \frac{1}{2} \times 8 \times (8 - 1.5) \right] = 10 \times 38 = 380\ kN/m$$

$$1\ c) \quad \gamma_{conc} = 2800\ kg/m^3$$

$$\text{Weight of the dam} = W = \gamma_{conc} \left[12 \times 2 + 6 \times 1 + \frac{1}{2} \times 11 \times 6 \right] = 1764\ kN/m$$

$$\therefore \text{Effective weight } W' = W - U = 1764 - 380 = 1384\ kN/m$$

$$\text{Friction angle} = 25^\circ$$

$$\therefore \text{Max Base shear} = W' \tan \phi = 1384 \tan 25^\circ = 645.37\ kN/m$$

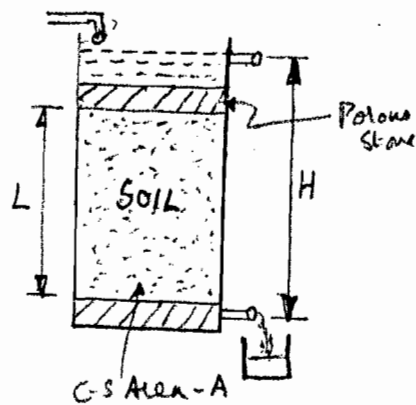
$$\text{Horizontal load due to water pressure} = \frac{1}{2} \times 100 \times 10 = 500\ kN/m$$

$$\therefore \text{FoS against sliding} = \frac{645.37}{500} = 1.29 \approx \underline{\underline{1.3}}$$

In reality, there will be some passive resistance offered by soil on the downstream toe of the dam, which increases the FoS against sliding.

[30%]

2 a)



A constant head permeameter is used to determine the hydraulic conductivity 'K' of a soil sample. The soil sample is held between porous stones. A constant head of water is applied along the sample, allowing the water to seep through the sample. The water is collected at the base

of the sample. The length of the soil sample 'L' and its cross-sectional area - 'A' are known. The constant head 'H' is the difference between the height of the water outlets at the base of the sample and the storage reservoir. The experiment involves measuring the volume of fluid coming out at the base in a given time t.

$$\text{Darcy's law } v = K i \Rightarrow v = K \frac{H}{L}$$

$$\text{Flow rate } Q = v \times A = K \frac{A H}{L}$$

$$\text{But } Q = \frac{V}{t} \text{ m}^3/\text{sec} \text{ is known.}$$

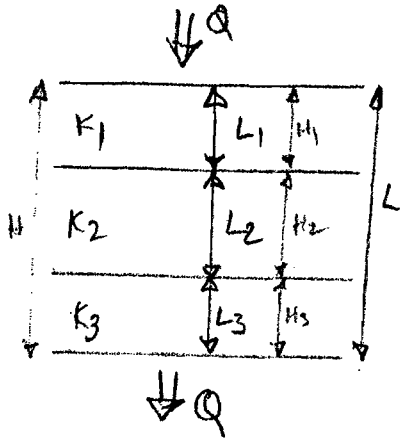
$$\therefore K = \frac{Q L}{A \cdot H} \text{ m/s}$$

The above expression can be used to measure the hydraulic conductivity 'K' of a soil sample.

However, for this apparatus to work we require decent flow of water through the soil sample in a reasonable time. Therefore, this is only useful for relatively high permeability or high hydraulic conductivity soils such as sands and silts. Low permeability soils such as clays cannot be tested in this apparatus.

(20)

2 b)



Consider horizontal layers of thicknesses L_1, L_2, L_3, \dots with hydraulic conductivities of K_1, K_2, K_3, \dots respectively. Let the drop in head in each layer be H_1, H_2, H_3, \dots . Let the total drop in head be 'H' and overall thickness of all the layers be 'L'. Consider a unit thickness normal to the plane of paper.

The same flow rate 'Q' must go through all the layers.

$$\therefore \text{Layer 1} \quad Q = K_1 i_1 \times 1 = K_1 \frac{H_1}{L_1} \times 1 \quad \Rightarrow H_1 = \frac{Q L_1}{K_1} \rightarrow \textcircled{1}$$

$$\text{Layer 2} \quad Q = K_2 i_2 \times 1 = K_2 \frac{H_2}{L_2} \times 1 \quad \Rightarrow H_2 = \frac{Q L_2}{K_2} \rightarrow \textcircled{2}$$

$$\text{Layer 3} \quad Q = K_3 i_3 \times 1 = K_3 \frac{H_3}{L_3} \times 1 \quad \Rightarrow H_3 = \frac{Q L_3}{K_3} \rightarrow \textcircled{3}$$

If the equivalent vertical hydraulic conductivity is K_{eq} for all the layers, then

$$Q = K_{eq} i_{eq} = K_{eq} \times \frac{H}{L} \times 1$$

$$\Rightarrow H = \frac{Q L}{K_{eq}} \rightarrow \textcircled{4}$$

$$\text{Total head } H = H_1 + H_2 + H_3 \quad ; \quad L = L_1 + L_2 + L_3$$

Substituting $\textcircled{1}, \textcircled{2}, \textcircled{3}$ and $\textcircled{4}$

$$\frac{Q L}{K_{eq}} = \frac{Q L_1}{K_1} + \frac{Q L_2}{K_2} + \frac{Q L_3}{K_3} \quad \Rightarrow \quad \frac{L}{K_{eq}} = \frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3} \dots$$

$$\text{QED} \therefore K_{eq} = \frac{L_1 + L_2 + L_3 + \dots + L_n}{\frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3} + \dots + \frac{L_n}{K_n}}$$

[30%]

$$2 c) \text{ Length of sample } L = 300 \text{ mm} = 0.3 \text{ m}$$

$$c-s \text{ Area} = \frac{\pi}{4} \times 0.2^2 = 0.0314 \text{ m}^2$$

$$\text{Applied } H = 1 \text{ m}$$

$$\text{Flow rate } Q = 600 \text{ cc in 5 minutes}$$

$$Q = \frac{0.6 \times 10^{-3}}{8 \times 60} = 1.25 \times 10^{-6} \text{ m}^3/\text{sec}$$

From 2(a) $K = \frac{Q L}{A H}$

$$\therefore K = \frac{1.25 \times 10^{-6} \times 0.3}{0.0314 \times 1} = 1.1937 \times 10^{-5} \text{ m/s}$$

The hydraulic conductivity obtained is consistent with that expected for a silty soil. [20%]

2(d) For this sample; $Q = \frac{300 \text{ cc}}{12 \text{ min}}$

$$\therefore Q = 4.167 \times 10^{-7} \text{ m}^3/\text{s}$$

$\therefore K = \frac{Q L}{A H}$ where L & A are as before but $H = 1.5 \text{ m}$

$$\therefore K = \frac{4.167 \times 10^{-7} \times 0.3}{\frac{\pi}{4} \times 0.2^2 \times 1.5} = 2.652582 \times 10^{-6} \text{ m/s}$$

This will be K_{eq} hydraulic conductivity for the whole system.

From part (c) we have $K_1 = 1.1937 \times 10^{-5} \text{ m/s}$, $L_1 = 0.3 - x$; where x is thickness of the rogue layer. $K_2 = 3.2 \times 10^{-9} \text{ m/s}$, $L_2 = x \text{ m}$. Using result from 2(b)

$$2.6526 \times 10^{-6} = \frac{0.3}{\frac{0.3-x}{1.1937 \times 10^{-5}} + \frac{x}{3.2 \times 10^{-9}}} \Rightarrow \text{Solve for 'x'}$$

$$\frac{0.3-x}{1.1937 \times 10^{-5}} + \frac{x}{3.2 \times 10^{-9}} = \frac{0.3}{2.6526 \times 10^{-6}} = 113097.3355$$

$$83773.14233(0.3-x) + 3125 \times 10^5 x = 113097.3355$$

$$x[3125 \times 10^5 - 83773.14] = 113097.3355 - 0.3 \times 83773.14233$$

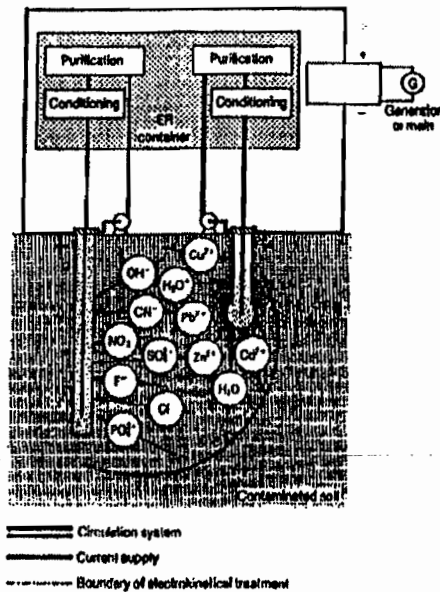
$$\therefore x = 2.8156 \times 10^{-4} \text{ m} \Rightarrow 0.28 \text{ mm}$$

\therefore The thickness of the rogue clay layer = 0.28 mm

[30%]

3 (a) (i) Electro-kinetic Remediation

A DC electric field is applied using ions to migrate according to their electric charge; water also migrates; electro-kinetics has potential for clean-up of low hydraulic conductivity soils contaminated with heavy metals



Advantages:

- Contaminants are removed from the soil
- Uses familiar technology
- Flexible
- Can contain the contaminant during clean-up so preventing further advective movement

Disadvantages:

- Expensive and long-term (may take decades)
- Inefficient as clean water also extracted
- Surface treatment necessary
- Needs good hydro-geological survey
- Pump-and-treat is effective in highly permeable soils only, and does not flush contaminants either sorbed or trapped in heterogeneities

[10%]

(ii) Thermal methods of clean-up

Heat is used to break up, destroy or immobilise contaminants. The range of thermal methods that can be used include:

• **Thermal desorption**

Volatile organic contaminant removed from soil and collected or treated e.g. by incineration in a second stage

• **Incineration**

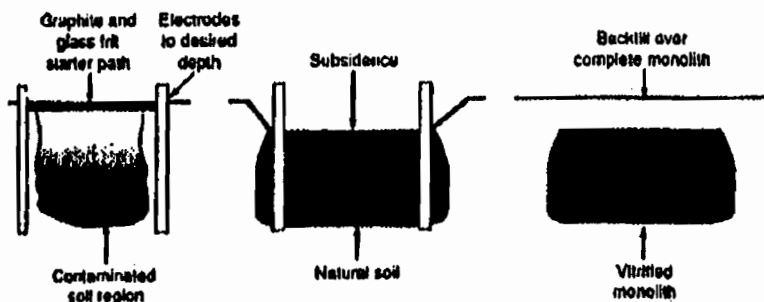
Organic contaminants are oxidised at high temperatures

• **Hot air/steam stripping and soil venting**

Volatile organic contaminants e.g. LNAPLs removed by pumping hot air or steam into soils

• **Vitrification**

Very high temperatures (up to 2000°C for some systems,) generated using large AC electric currents are applied to destroy organic contaminants and trap others in a glassy product due to melting soil grains.



Advantages:

- The hazardous properties of contaminants are permanently reduced
- Uses well-established technology

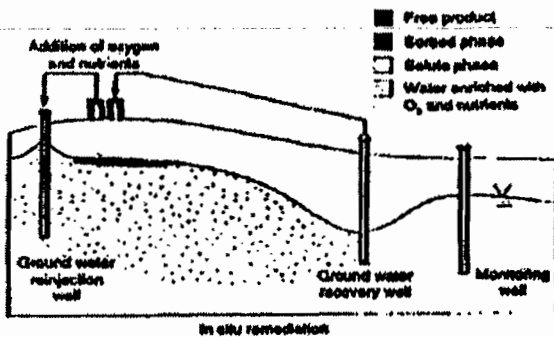
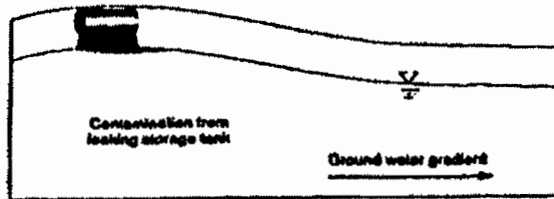
Disadvantages:

- Generally very expensive
- May produce gas and particle emissions
- Metals are not destroyed

[15%]

(iii) Biological methods of clean-up

In bioremediation, living micro-organisms are used to destroy, remove or transform the hazardous contaminant. It is necessary to optimise the biological activity in anaerobic/aerobic conditions and is applied both *ex-situ* and *in-situ*.



Advantages:

- the hazardous properties of the contaminants are permanently reduced
- naturally occurring microbes present in the soil can be used
- could be inexpensive
- particularly suited to organic contaminants, and suitable containment-specific micro-organisms may be available

Disadvantages:

- a more toxic product may be produced
- nutrients and oxygen (for aerobic micro-organisms) need to be supplied
- gas and odours are produced e.g. methane
- some organic pollutants are not easily degraded
- the reaction may be slowed by the presence of heavy metals or pesticides
- long treatment times may be necessary

[15%]

3 (b) (i) RDA's primary role is as strategic drivers of regional economic development in their region. RDAs aim to co-ordinate regional economic development and regeneration

Each Agency has five statutory purposes:

- To further economic development and regeneration
- To promote business efficiency, investment and competitiveness
- To promote employment
- To enhance development and application of skill relevant to employment
- To contribute to sustainable development [20%]

(ii) Use of energy in construction projects and buildings:

Problems:

Servicing buildings accounts for approximately 50% of UK's total energy consumption.

In construction projects energy is used:

- To manufacture and transport building materials and products (embodied energy)
- To create the structure on site
- To operate the building/structure throughout its lifetime (in-use energy)
- To transport people and goods between the buildings (transport energy)
- To demolish and transport demolition waste

SEEDA checklist:

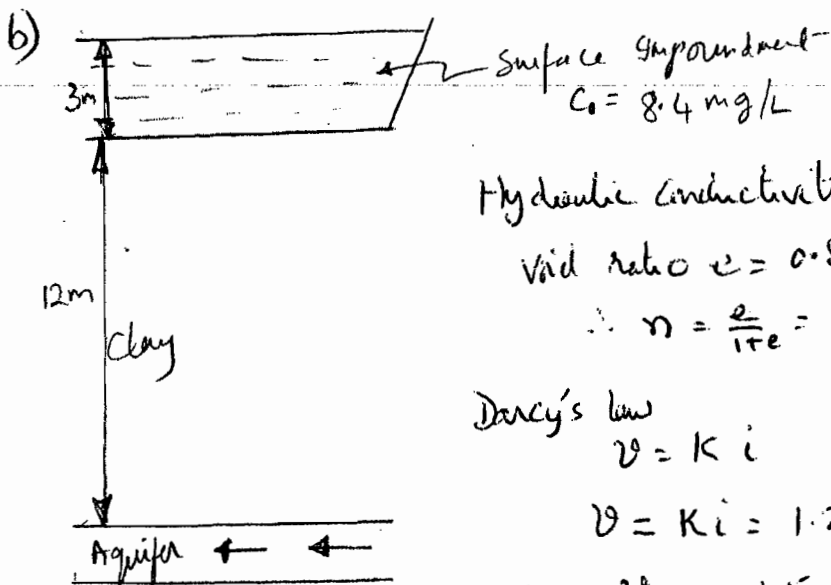
- Minimise use of energy in construction and in running the buildings.
- Energy from renewable sources (wind, hydro, solar etc) to be used as much as possible.

SnOasis implementation:

- Internal climate control within the buildings will be controlled with the fundamental aim of minimising energy consumption.
- Where possible natural ventilation will be used
- Building physics, in respect of the orientation of the buildings, will assist in controlling the temperature
- Insulation will be maximised in buildings which require all-year round cooling
- Energy consumption will be continually monitored within the project by a building management system
- Plan is to generate own energy in future
- Currently energy is being taken from landfill site next door [30%]

4 a) Sorption is the process by which a contaminant is attached to the surface of the soil grains. The clay particles can have more affinity to one type of ion compared to others and therefore leading to the sorption of that ion. Desorption is when an ion already on the surface of the soil particle is kicked out by ions which are preferentially sorbed to the soil particle.

Sorption has the effect of retarding the transport of the contaminant through the porous medium. In other words, the transport of the contaminant is 'delayed' due to the sorption process. [10%]



$$\text{Hydraulic conductivity } K = 1.2 \times 10^{-9} \text{ m/s}$$

$$\text{Void ratio } e = 0.8$$

$$\therefore n = \frac{e}{1+e} = 0.44$$

Darcy's law

$$v = K i \quad i = \frac{H}{L} = \frac{15}{12} = 1.25$$

$$v = K i = 1.2 \times 10^{-9} \times 1.25 = 1.5 \times 10^{-9} \text{ m/s}$$

$$v_f = \frac{v}{n} = \frac{1.5 \times 10^{-9}}{0.44} = 3.375 \times 10^{-9} \text{ m/s}$$

Coefficient of hydrodynamic dispersion $D_L = D_d^* + D = D_d^* + \alpha_L v_f$

$$\therefore D_L = 2.3 \times 10^{-9} + 0.3 \times 3.375 \times 10^{-9} = 3.3125 \times 10^{-9} \text{ m}^2/\text{s}$$

i) Break through time:

$$\frac{C}{C_0} = \frac{1}{2} \operatorname{erfc} \left[\frac{z - v_f t}{\sqrt{4 D_L t}} \right]$$

$$\frac{C}{C_0} = 0.0001$$

$$\operatorname{erfc} \beta = 0.0002$$

From erfc tables in the data book

$$\beta = 2.6$$

$$\frac{z - v_f t}{\sqrt{4 D_L t}} = 2.6 ; \quad z = 12 \text{ m} \quad v_f = 3.375 \times 10^{-9} \text{ m/s} \\ D_L = 3.3125 \times 10^{-9} \text{ m}^2/\text{s}$$

$$\frac{12 - 3.375 \times 10^{-9} t}{2.6} = \sqrt{4 \times 3.3125 \times 10^{-9} t^{1/2}}$$

$$4.61538 - 1.2981 t \times 10^{-9} = \sqrt{t} \times 1.1511 \times 10^{-4}$$

Solving this quadratic in \sqrt{t} for +ve t gives

$$t = 898090503.6 \text{ sec or } \underline{28.5 \text{ years}}$$

3 b ii) At Quarter depth $z = 3 \text{ m}$.

$$\frac{C}{C_0} = \frac{1}{2} \operatorname{erfc} \left[\frac{3 - 3.375 \times 10^{-9} \times 898090503.6}{\sqrt{4 \times 3.3125 \times 10^{-9} \times 8.9 \times 10^8}} \right]$$

$$\frac{C}{C_0} = \frac{1}{2} \operatorname{erfc}(-0.009) = \frac{1}{2} \times 1.001$$

$$C = 8.4 \times 0.5005 = \underline{4.2043 \text{ mg/L}}$$

At Half depth $z = 6 \text{ m}$

$$\frac{C}{C_0} = \frac{1}{2} \operatorname{erfc} \left[\frac{6 - 3.375 \times 10^{-9} \times 8.98 \times 10^8}{\sqrt{4 \times 3.3125 \times 10^{-9} \times 8.9 \times 10^8}} \right]$$

$$= \frac{1}{2} \operatorname{erfc}(0.86066)$$

$$\frac{C}{C_0} = \frac{1}{2} \times 0.22369$$

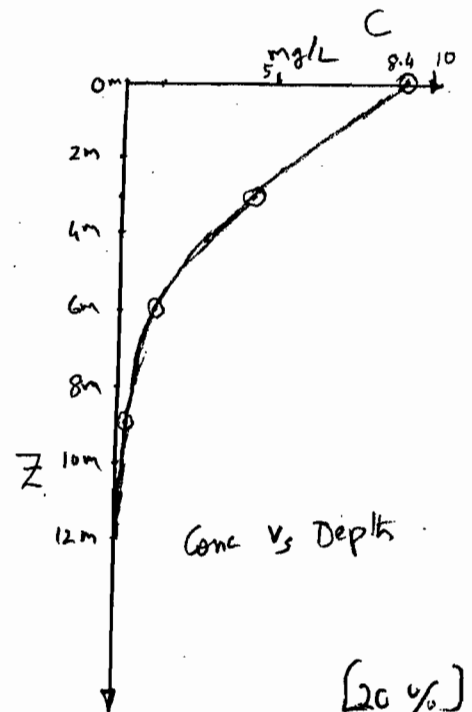
$$C = \underline{0.9395 \text{ mg/L}}$$

At 3/4 depth $z = 9 \text{ m}$

$$\frac{C}{C_0} = \frac{1}{2} \operatorname{erfc} \left[\frac{9 - 3.375 \times 10^{-9} \times 8.98 \times 10^8}{\sqrt{4 \times 3.3125 \times 10^{-9} \times 8.9 \times 10^8}} \right]$$

$$= \frac{1}{2} \operatorname{erfc}(1.7303) = \frac{1}{2} \times 0.0145941$$

$$C = \underline{0.0613 \text{ mg/L}}$$



4 (b) (i) Level 1 - Basic Characterisation:

Usually the responsibility of waste producer or current holder of waste (if producer cannot be identified):

- Chemical composition and leaching tests against WAC
- Determines key variables in the waste
- Determines potential for environmental impact or harm to health
- Hence determine which class of landfills may receive it
- Assess the variability of the waste
- Determines the parameters to be assessed in levels 2 and 3, checking and the frequency of those checks

Level 2: Compliance checking

Level 3: On-site verification

Responsibility of landfill operator, who needs to liaise with waste producer, as approach relies on the information from basic characterisation. Checking of a limited number of parameters.

Level 2: waste is periodically checked to ensure that properties have not changed.

Level 3: waste is checked at the landfill to verify that it is the expected waste and has not been contaminated in storage or transport. [30%]

(ii) New EU leaching tests for wastes (BS EN 12457, Parts 1 to 4):

- 100g of waste, sometimes needs to be crushed
- Extraction fluid: water with pH of 5-7 (slightly acidic to simulate acid rain)
- Liquid:Solid ratio mainly 10:1
- Mix agitated for 18-24 hours
- Leachate filtered and analysed, concentration in mg/L, converted to mg/kg of waste (x10) [20%]