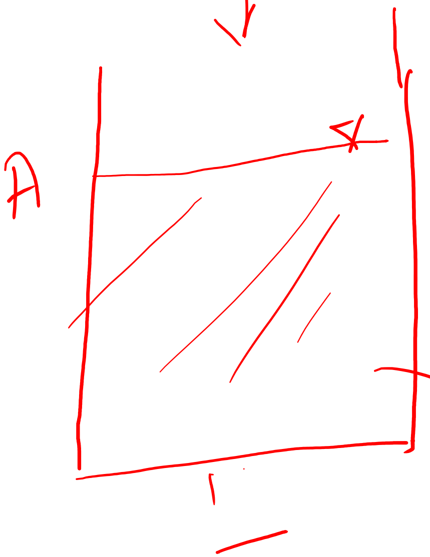
Groundwater


clay
sand
silty clay
sand
clay
Rock

200ml water



1L

→ Sand

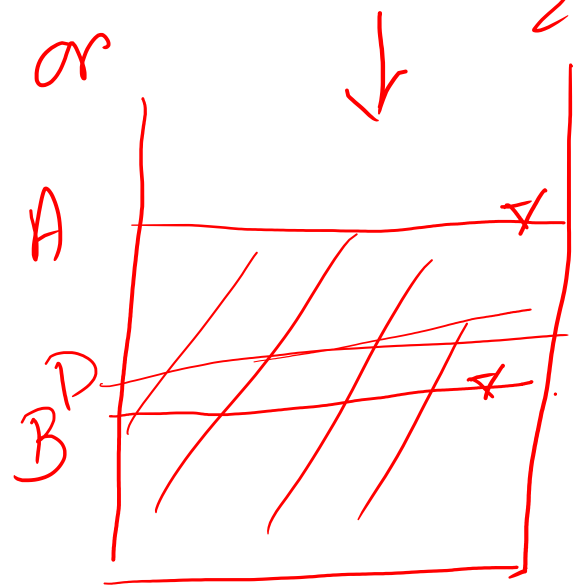
voids

pores

→ 20ml

pore volm = 200ml

water 200ml



1L

C

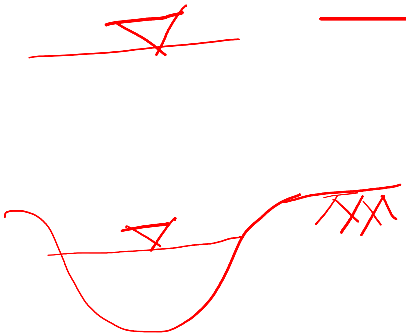
AB → Unsaturated zone or Zone of aeration

BC → Saturated zone

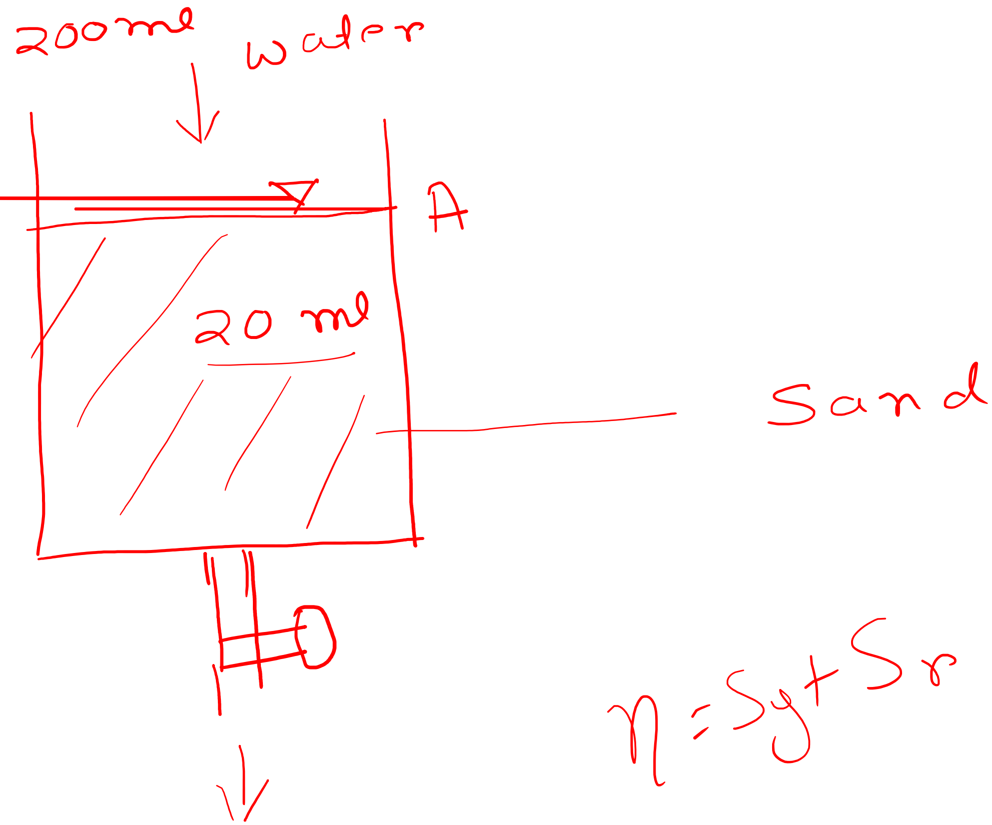
BD → Capillary fringe

H_2O

100ml



1000 ml



$$\frac{200\,ml}{1000\,ml} \times 100\%$$

$\Rightarrow 20\%$

$$\frac{20}{1000} \times 100\%$$

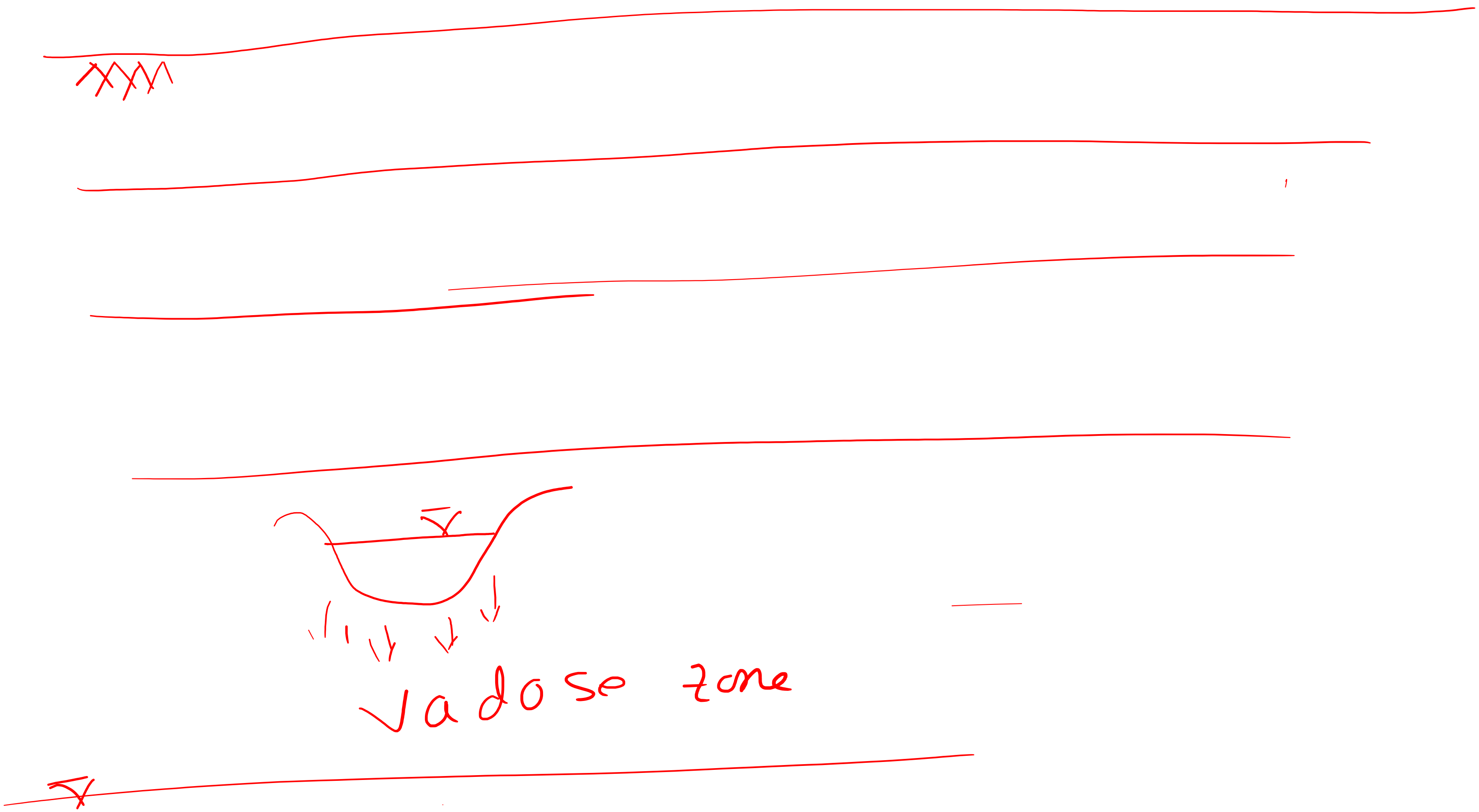
$\Rightarrow 2\%$

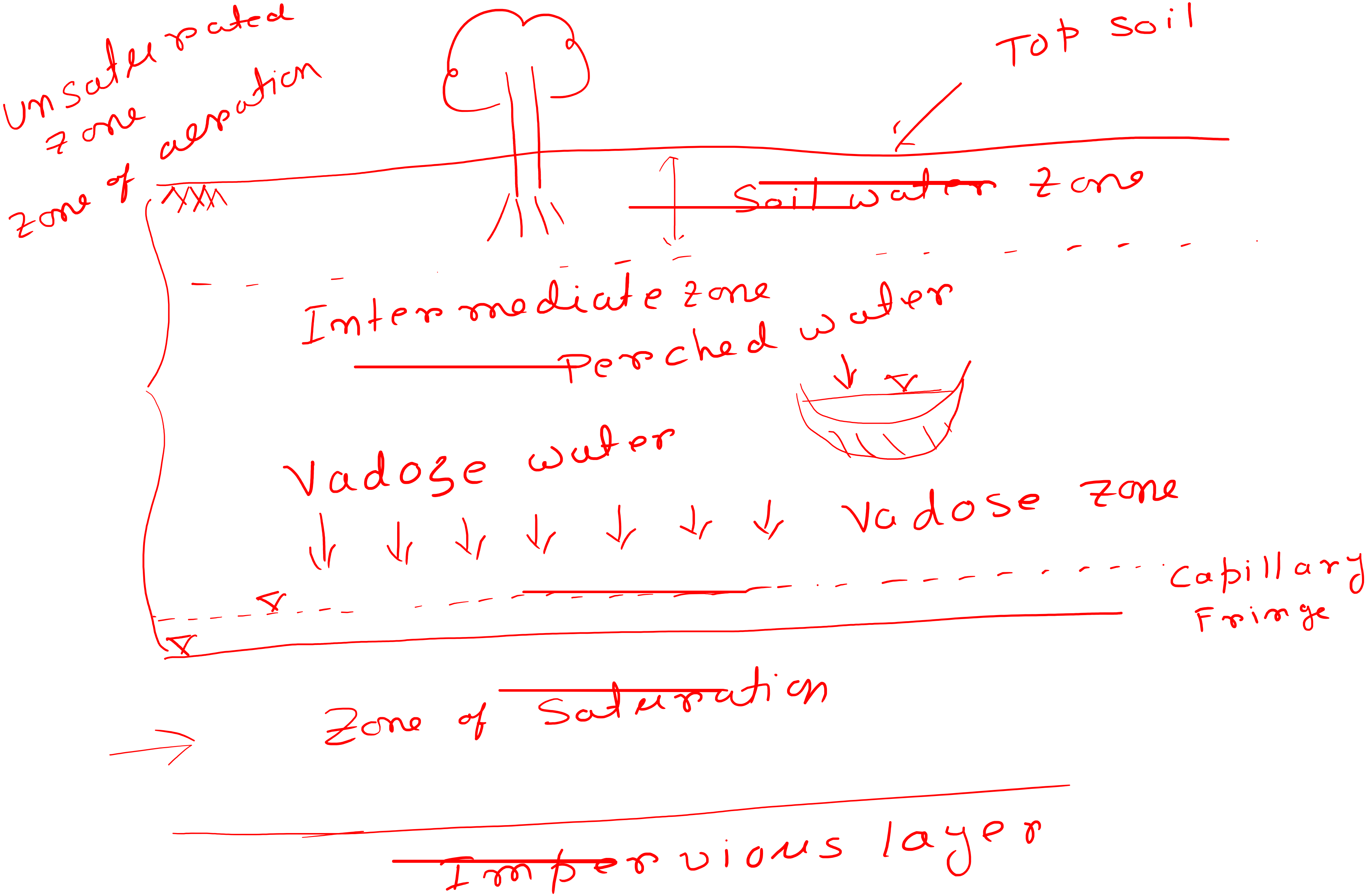
180 ml

$$\eta = S_y + S_r$$

$$\frac{180}{1000} \times 100\% = 18\%$$

ground water


Vadose zone

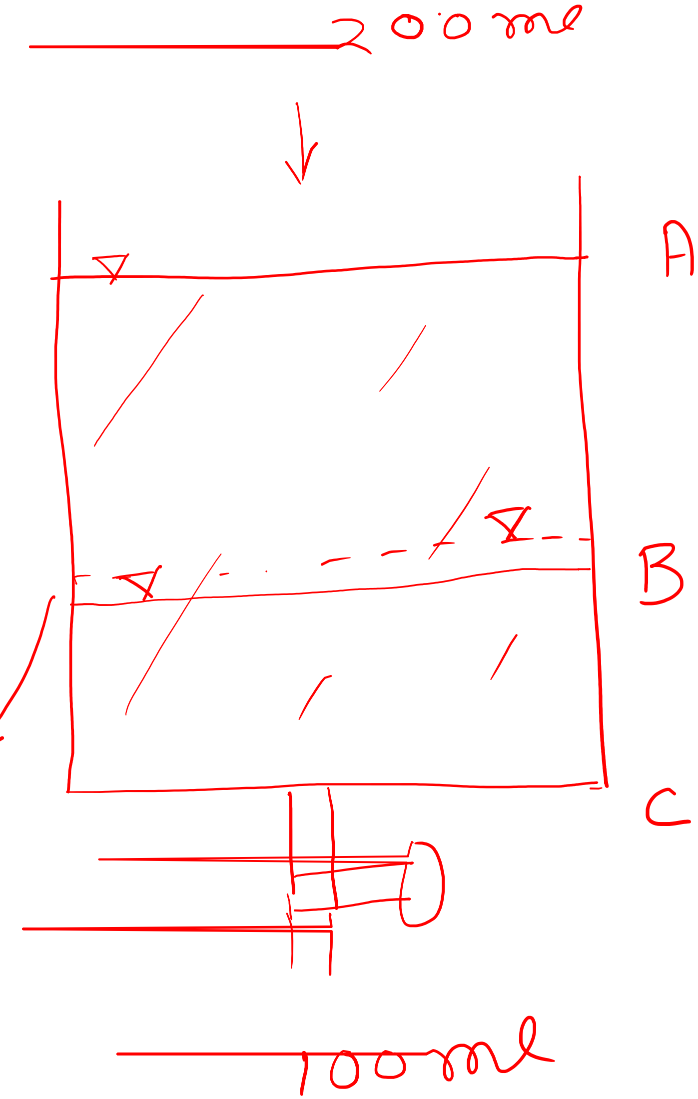

Unsaturated zone
Zone of aeration
Top soil
Soil water zone
Intermediate zone
Perched water
Vadose water
Vadose zone
Capillary Fringe
Zone of Saturation
Impervious layer

Pores or voids

Unsaturated zone or
Zone of aeration

Zone of Saturation

capillary fringe



- **Porosity (n):** The amount of pore space present per unit volume of the soil or sediment is called porosity. Normally porosity represented in percentage.

$$n = \frac{V_v}{V_0}\ x100\%$$

- **Specific retention (S_r)** is that volume fraction of water that is held back by adhesion and capillary forces, when an aquifer is drained.

$$S_r = \frac{V_r}{V_0} \mathrm{x}100\%$$

- **Specific yield (S_y)** is the amount of water that is actually available for groundwater pumping, when sediments or rocks are drained due to lowering of the water table.

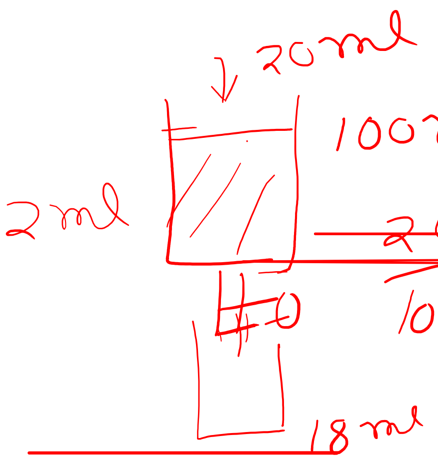
$$S_y = \frac{V_d}{V_0} \mathrm{x}100\%$$

Where, V_v = Volume of voids
V_0 = Total Volume of Soil
V_d = volume of water that drains from a total volume of V_0
V_r = Volume of water retained in a total volume of V_0

$$n = S_y + S_r$$

Table 3. Selected Values of Porosity, Specific Yield, and Specific Retention
[Values in percent by volume]

Material	Porosity	Specific Yield	Specific Retention
Soil	55	40	15
Clay	50	2	48
Sand	25	22	3
Gravel	20	19	1
Limestone	20	18	2
Sandstone (semiconsolidated)	11	6	5
Granite	.1	.09	.01
Basalt (young)	11	8	3



$$\frac{20}{100} \times 100\% = 20\%$$

$$\frac{2}{100} \times 100\% = 2\%$$

$$\frac{18}{100} \times 100\% = 18\%$$

Source: EPA/625/4-85/016
(http://web.eng.fiu.edu/fuentes/CWR%206125%20-%20GWH%20S%202018%20Public/Handouts/Part%20I/7B.%20Specific%20Yield%20&%20Specific%20Retention.pdf)

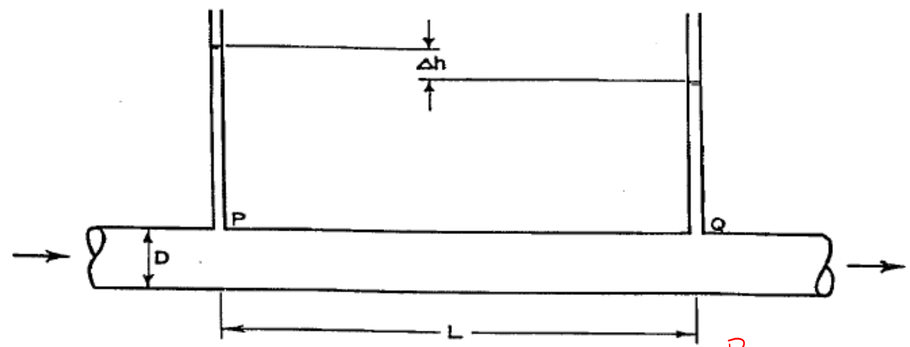
- Permeability: is how well water flows through rock or other earth substance under the action of gravity. Factors that affect permeability are how large the pores in the substance are and how well the particles fit together.

Darcy's Law: Darcy, in 1856, found that velocity was proportional to the first power of i

Where, V = Velocity, m/sec

Q = Discharge, m^3/sec

i = Hydraulic gradient $i = \dfrac{\Delta h}{L}$



A

B

Darcy's Law can be expressed as:

$Q = A \cdot V$

$V \propto i$

or

$V = ki$ cm/sec , m/sec

$Q = kiA$

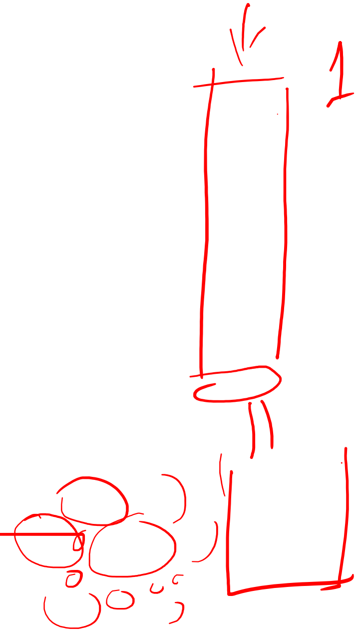
1 cm

Where, k= Permeability

A = Cross sectional area of pipe

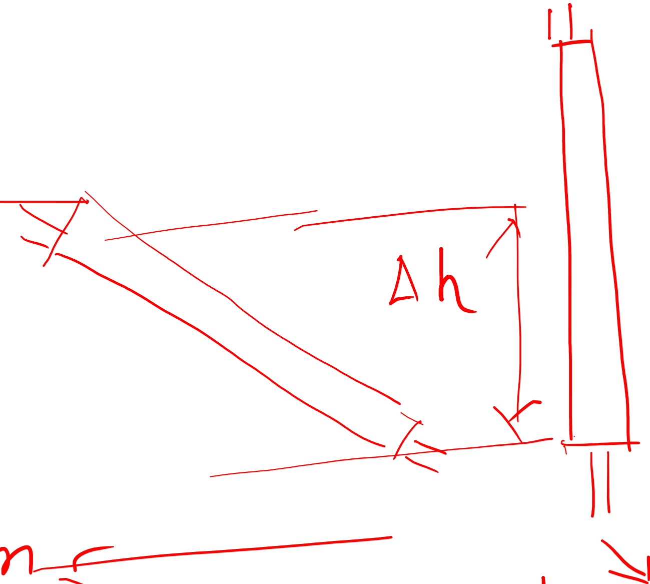
TYPICAL VALUES OF PERMEABILITY

Gravel	greater than 10^{-2} m/sec
Sand	10^{-6} m/sec to 10^{-2} m/sec
Silt	10^{-9} m/sec to 10^{-5} m/sec
Clay	10^{-11} m/sec to 10^{-8} m/sec

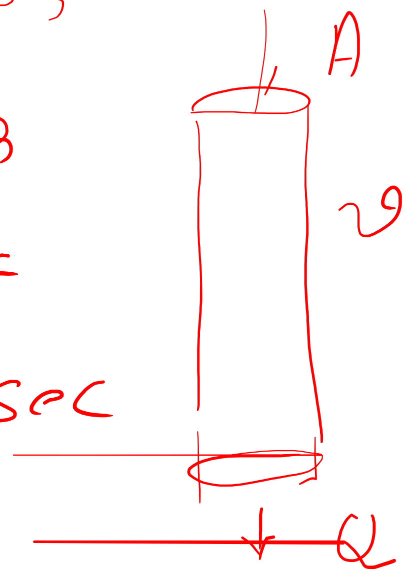


1 cm^2

$$\frac{180 \text{ ml}}{1 \text{ min}}$$



$$\frac{\Delta h}{L} \quad i = 1$$



$$Q = \frac{180 \text{ cm}^3}{60 \text{ Sec}}$$

$$= 3 \text{ cm}^3/\text{Sec}$$

Discharge

$$Q = K\, i\, A$$

$$K = \frac{Q}{i A} = \frac{3}{1 \cdot 1 \cdot}$$

$$Q = A \cdot v$$

cm3/sec

m3/sec

$K = 3$ cm/sec

Types of Geological Formations

1. **Aquifer:** An aquifer is a saturated formation of the earth. It not only stores the water but also yields it in adequate quantity. Aquifers are highly permeable formations and hence they are considered as main sources of groundwater applications. Unconsolidated deposits of sand and gravel are examples of an aquifer.

- Aquifers are classified into two types based on their occurrence which are as follows :
    i. Unconfined aquifer
    ii. Confined Aquifer

Unconfined aquifer: An unconfined aquifer is an aquifer which has free water surface – which means the water table exists for this type of aquifer. This is also called as water table aquifer or free aquifer or phreatic aquifer. Unconfined aquifers are recharged by the infiltration of precipitation from the ground surface.

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Source: https://theconstructor.org/geotechnical/types-geological-formations-groundwater/34672/

- **Confined Aquifer:** A confined aquifer is an aquifer confined between two impermeable beds such as aquifuge, aquiclude, etc. The water in the confined aquifer will be under greater pressure which is greater than atmospheric pressure. Hence, the water level shown by piezometer is always higher than the top level of the confined aquifer. The recharge of confined aquifer occurs at a place where it exposes to the ground surface.

Source: https://theconstructor.org/geotechnical/types-geological-formations-groundwater/34672/

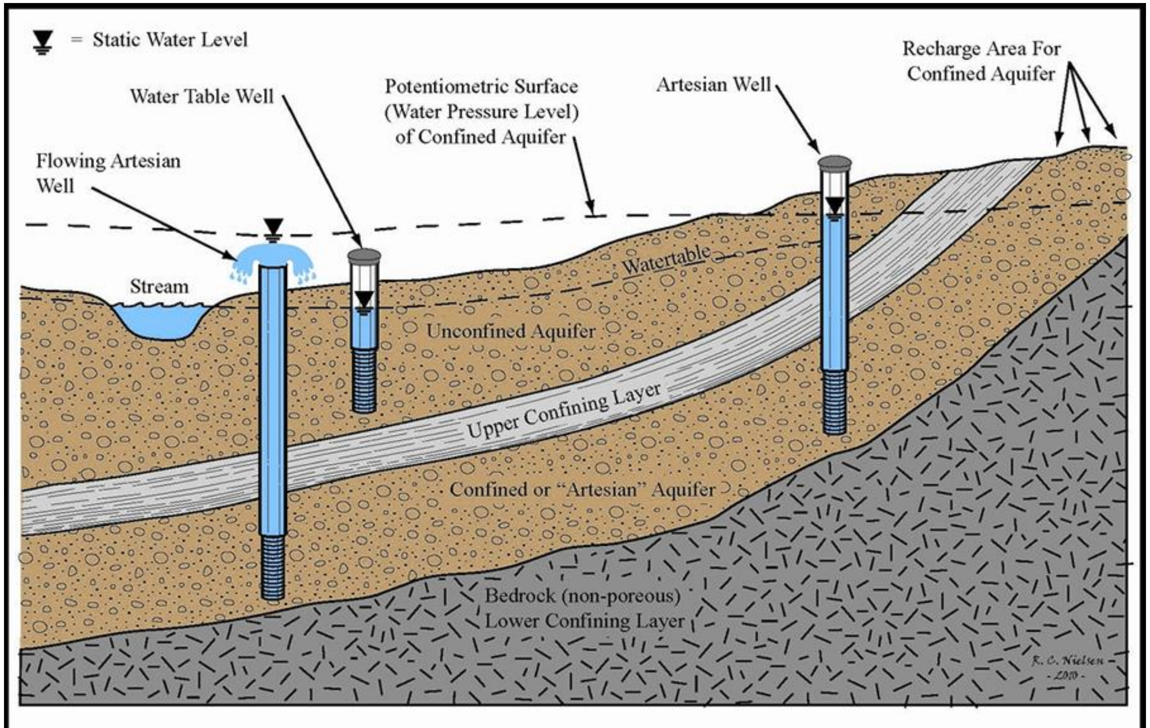
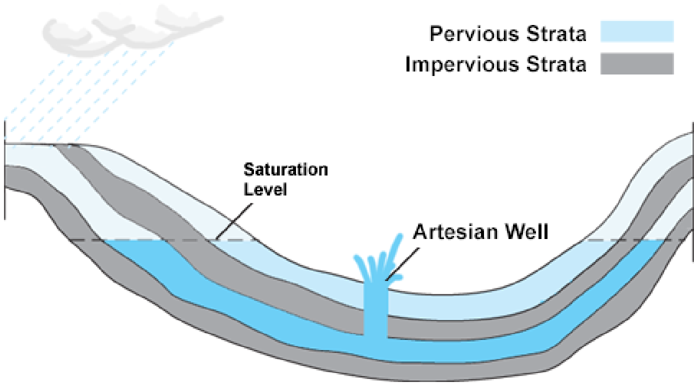


Figure 1. Terms Relating To Flowing Artesian Wells

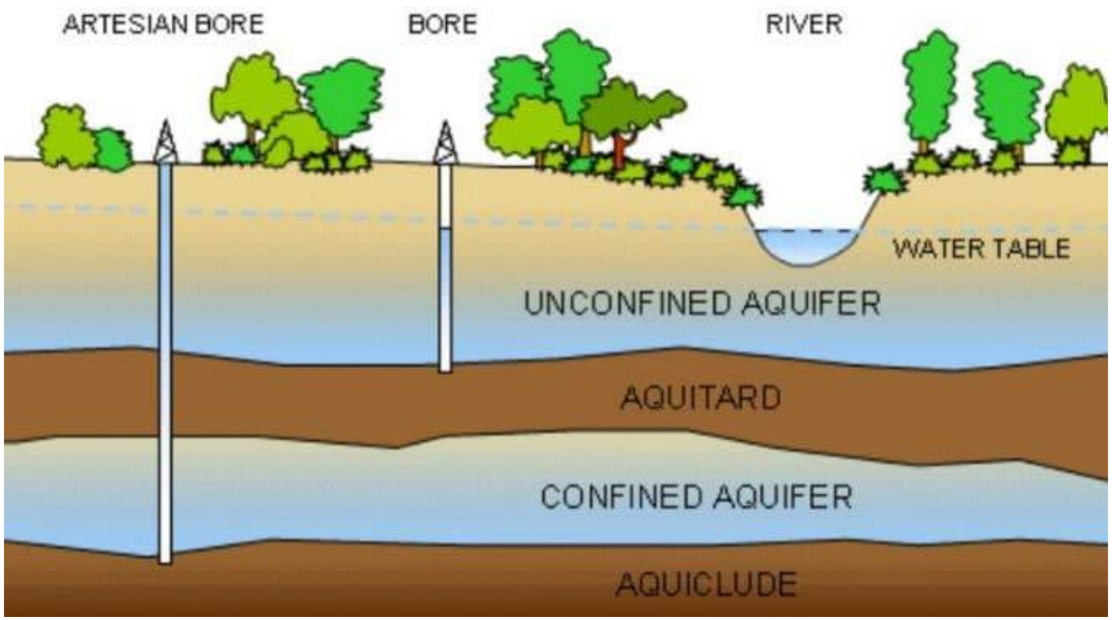


Source:https://blogs.egu.eu/network/geosphere/tag/artesian/

Source:https://blogs.egu.eu/network/geosphere/files/2015/11/flowingwell.jpg

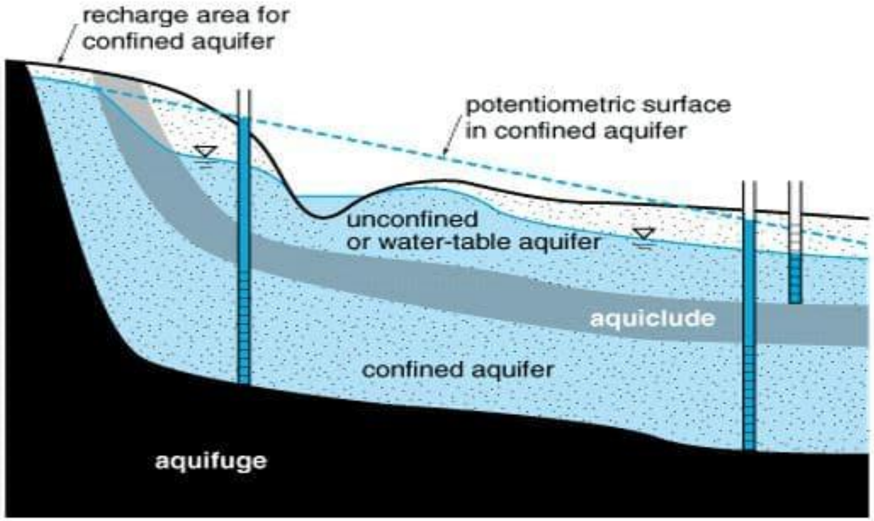
2. Aquitard: An aquitard is also a saturated formation. It permits the water through it but does not yield water in sufficient quantity as much as aquifer does. It is because of their partly permeable nature. But however, if there is an aquifer under the aquitard then the water from aquitard may seep into the aquifer. **Sandy clay** is a perfect example of an aquitard. Here, the clay particles block the voids present in the sand and make it partly permeable.

3. Aquiclude: An aquiclude is a geological formation which is impermeable to the flow of water. It contains a large amount of water in it but it does not permit water through it and also does not yield water. It is because of its high porosity. **Clay** is an example of aquiclude.



Source: https://theconstructor.org/geotechnical/types-geological-formations-groundwater/34672/

4. Aquifuge: An aquifuge is an impermeable geological formation which is neither porous nor permeable – which means it cannot store water in it and at the same time it cannot permit water through it. **Compact rock** is an example of aquifuge.



Source: https://theconstructor.org/geotechnical/types-geological-formations-groundwater/34672/

Comparison of formations

Geological formations/ Properties	Aquifer	Aquitard	Aquiclude	Aquifuge
Water storage	Yes	Yes	Yes	No
Permeability of water	Permeable	Partly permeable	Impermeable	Impermeable
Yield of water	Yes	Yes but slow yielding	Do not yield	Do not yield
Examples	Sand, Gravel	Sandy clay	Clay	Compact rocks such as granite, basalt etc.

Source: https://theconstructor.org/geotechnical/types-geological-formations-groundwater/34672/

Influent and Effluent river

- **Effluent river:** Effluent rivers are streams which get their water from the groundwater. The surface of the stream directly relates to the surface of the groundwater (called the water table), and the stream will rise and fall as the water table rises and falls. Examples of effluent rivers include the Amazon River in South America, the Mississippi River in the United States, and the Columbia River in the Pacific North West of North America.

Influent Stream: An influent river, also known as a losing stream or a sinking stream, is a type of stream that loses water as it flows downstream. Influent river systems lose their water to the underlying bedrock through percolation and enriching the underlying aquifer. Some losing streams include the Nile River, which is one of the longest rivers in the world.

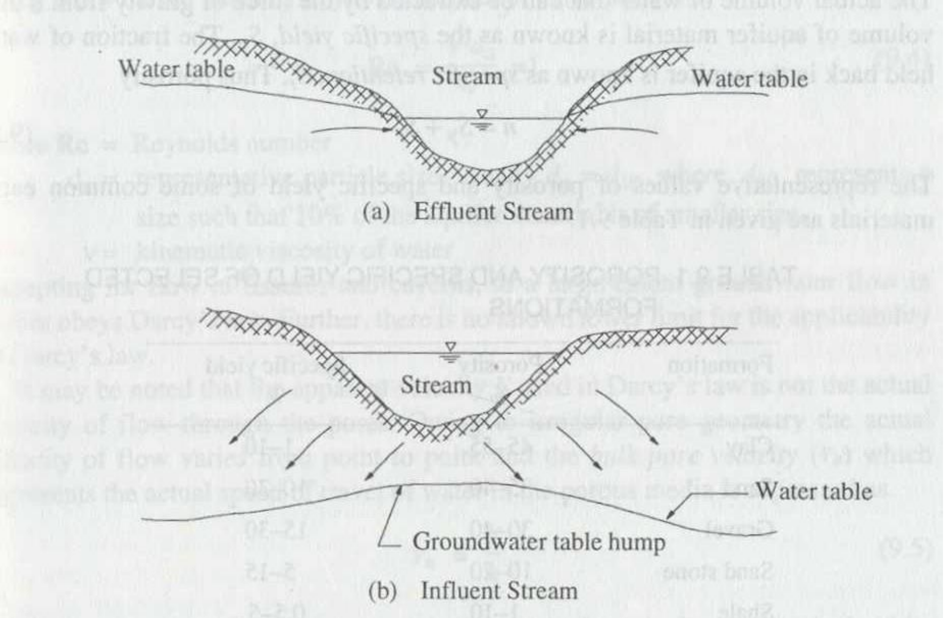


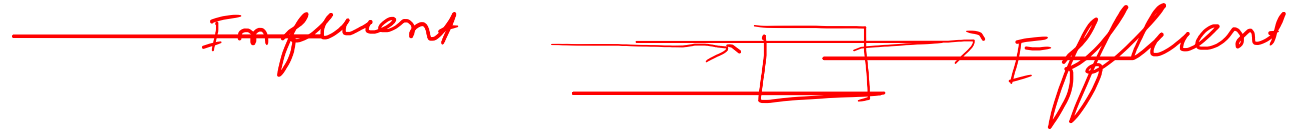
Fig. 9.4 Effluent and influent streams

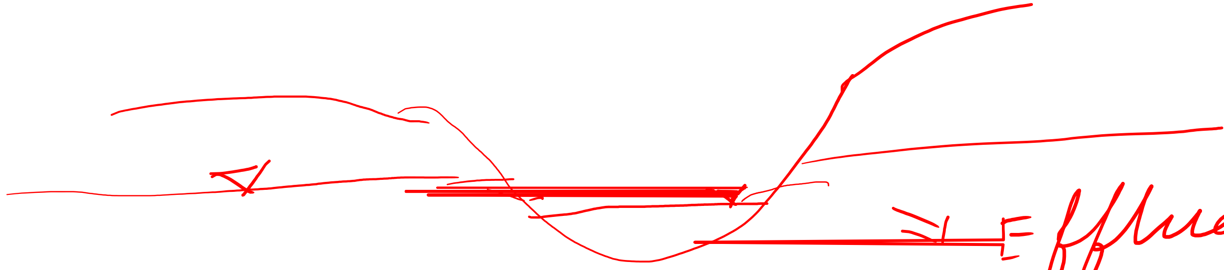
Source https://www.worldatlas.com/articles/what-is-the-difference-between-an-influent-and-an-effluent-stream.html
http://jersey.uoregon.edu/~mstrick/AskGeoMan/geoQuerry62.html
https://www.padeepz.net/water-table-aquifer-properties/

Water Pollution Sources

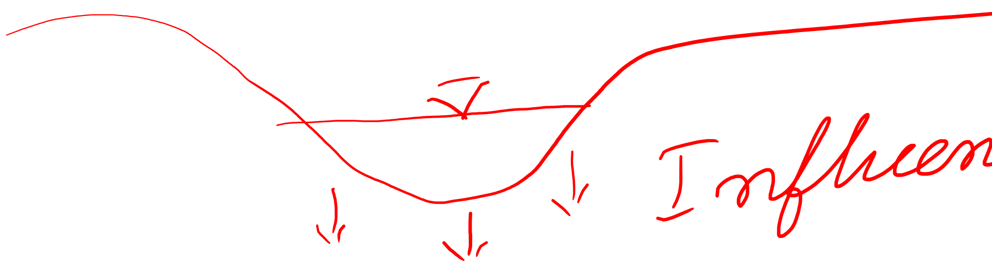
- Water pollution is the contamination of water bodies e.g. lakes, rivers, oceans and groundwater.
- Water pollution occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds.
- Water pollution affects plants and organisms living in these bodies of water.
- The effect is damaging to individual species and populations and natural biological communities.

Source: https://nptel.ac.in/content/storage2/courses/105101010/downloads/Lecture28.pdf

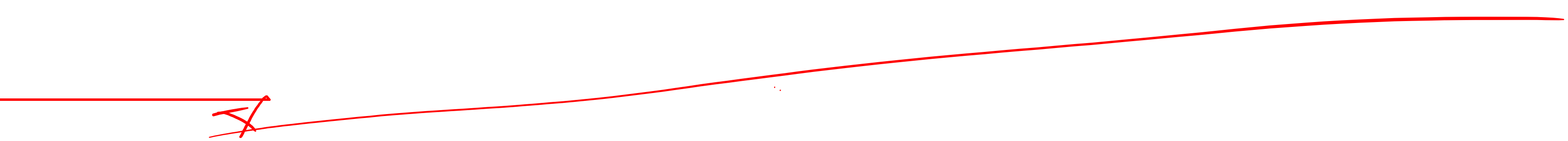


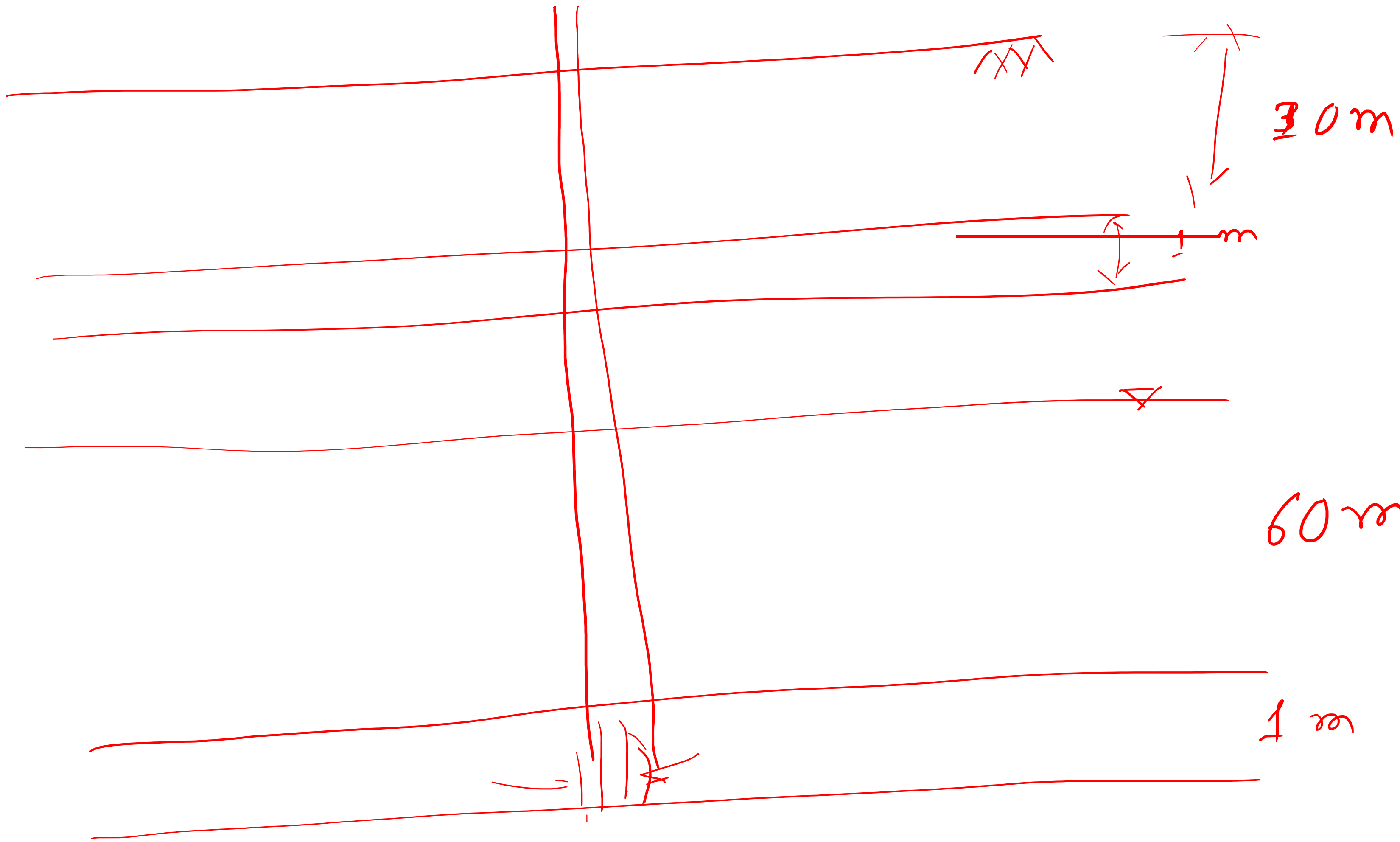


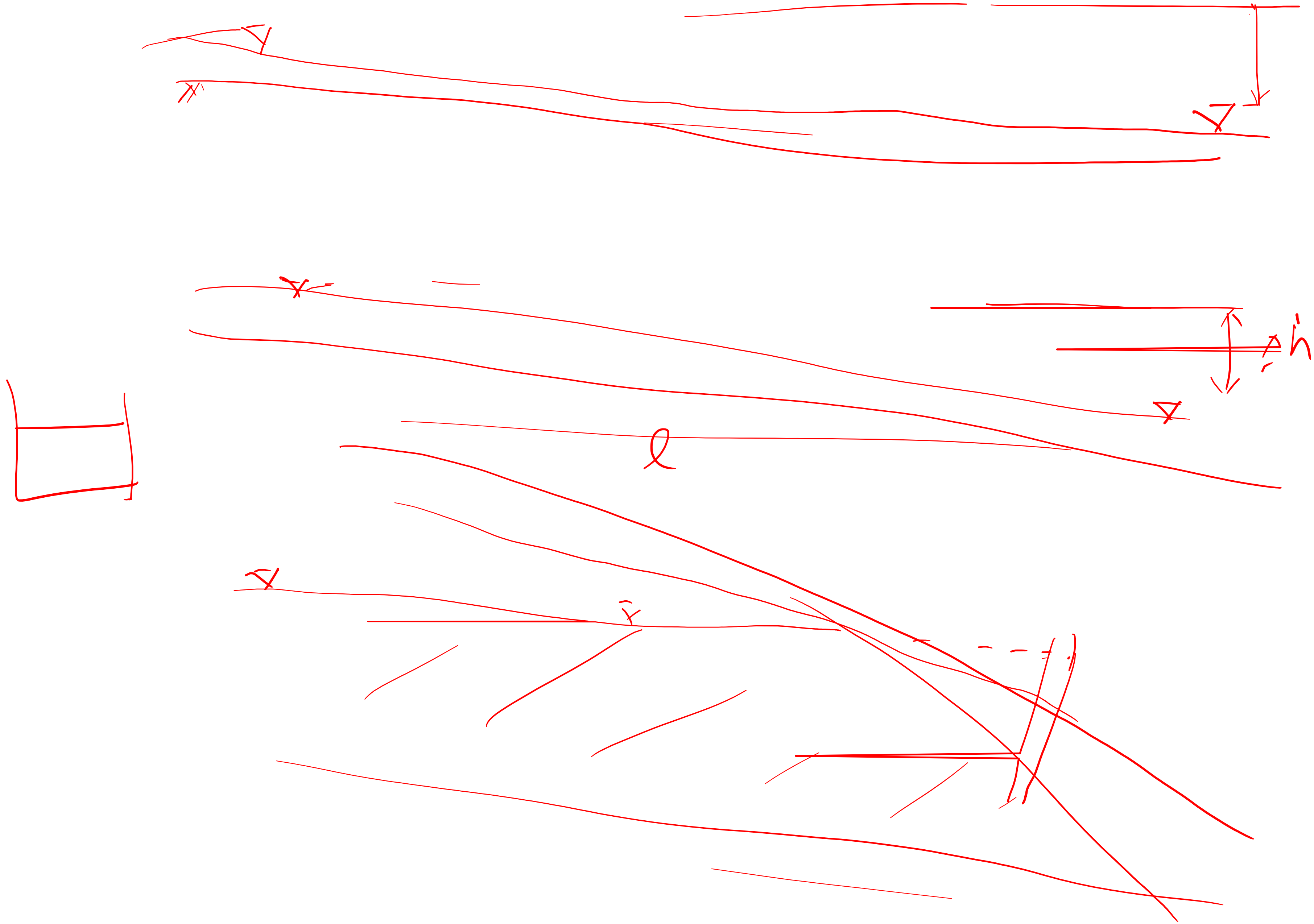
Effluent river



Influent river




30 m
1 m
60 m
1 m



TDS → Total dissolved solids

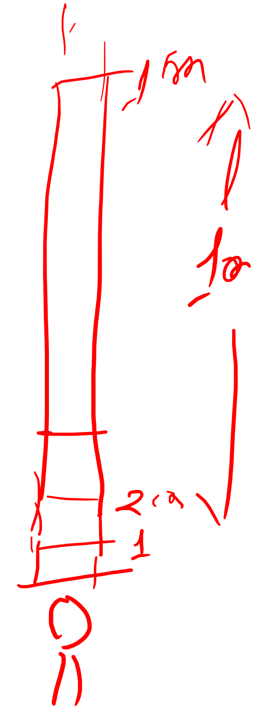
Na, Cl, HCO_3^-

K, NO_3^-, CO_3

Mg, PO_4,

→ 100 mg/l

1000 mg/l



physical parameter

Color, Odor, Taste, pH,

10 mg/l

Total Solids (TS)

TSS → TSS → FS, VS   Turbidity → 5 NTU

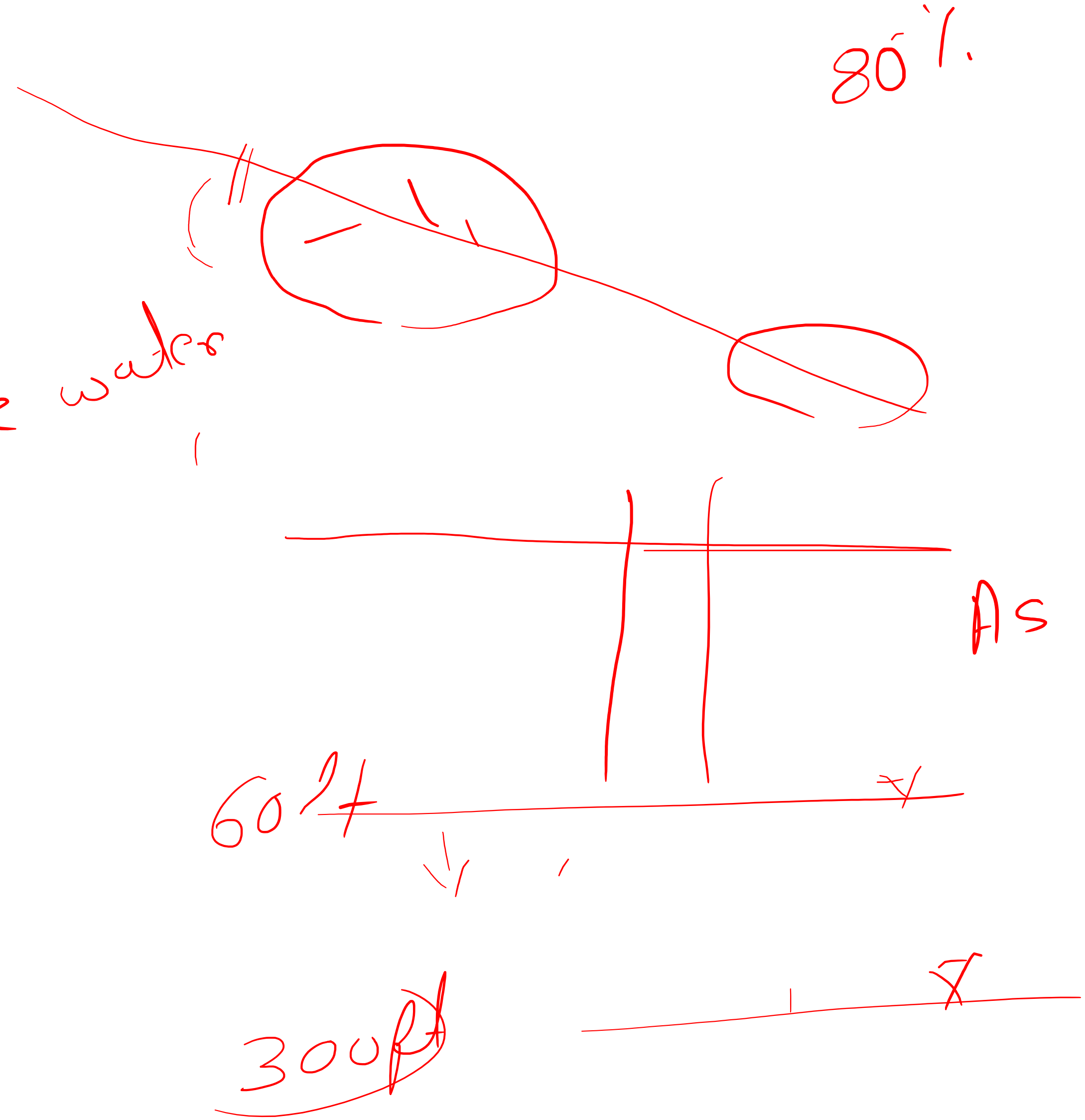
TDS → FS, VS

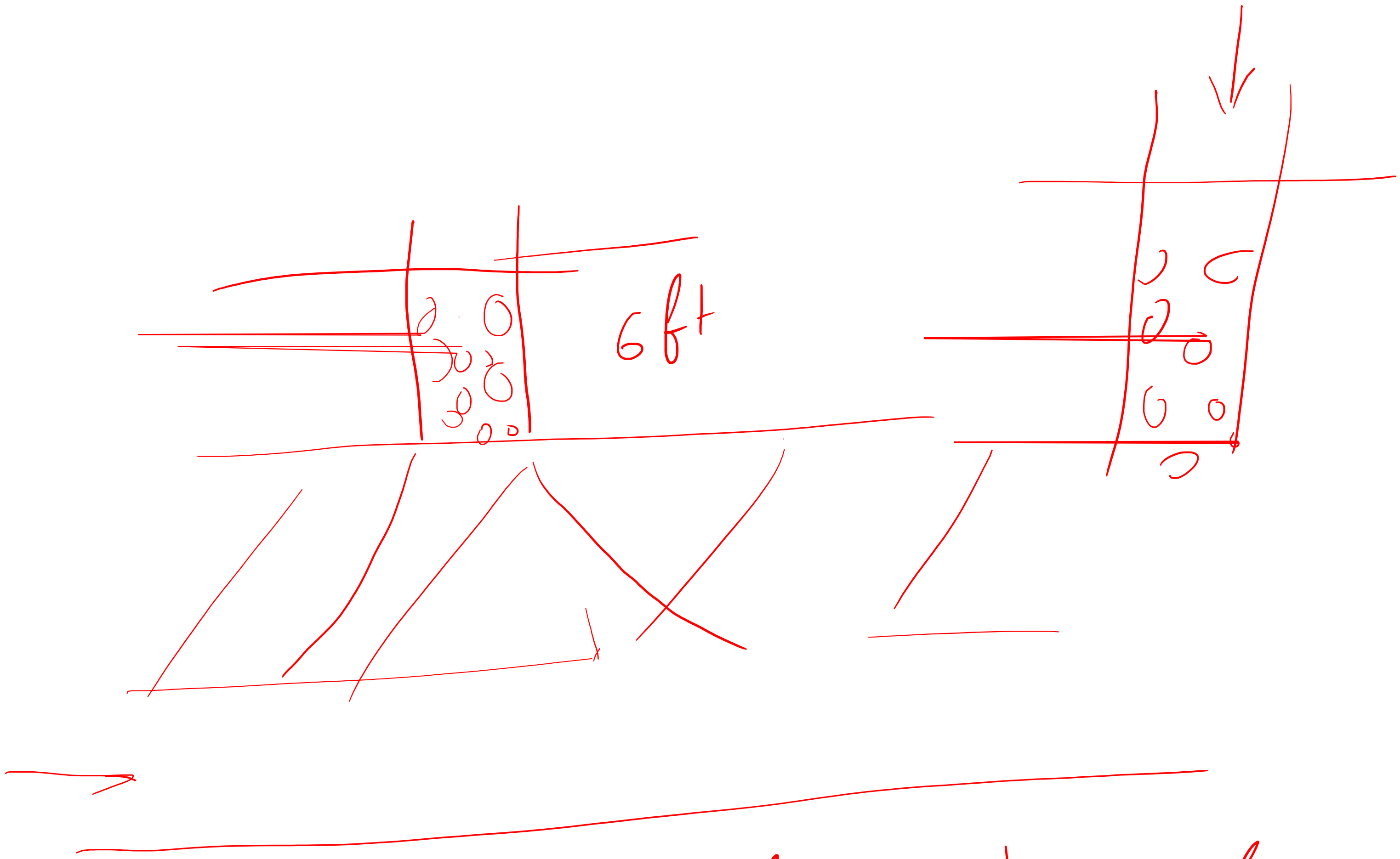
BOD →

COD →

1. Municipal w/w
2. Industries
3. Agriculture water

F





Artificial recharge of groundwater

135 l/person/day → 80%

Organic ~~matter~~ → microbs

DO → Dissolve Oxygen ~~DO → 10-12 mg/l~~

4 ~~gm~~ mg/l

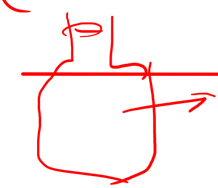
BOD → Biochemical Oxygen Demand

COD → chemical " "

BOD : COD → ~~1 : 3~~

7 mg/le

4 mg/l

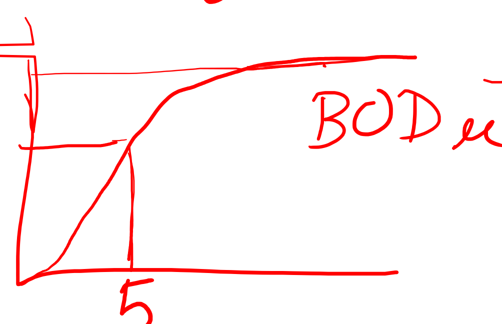


→ DO

after 5 days

BOD_5 =

↓ 60%



→ 3 mg/l

Water Pollution – Source Types

- Water Pollution – Point or non-point sources
- Water pollution- point sources: contaminants that enter a waterway from a single, identifiable source, such as a pipeor ditch.
- Traced to a specific source
- Leaking chemical tank, effluents coming from a waste treatment or industrial plant, or a manure spill from a hog confinement lagoon

Examples

– discharges from a sewage treatment plant; a factory; a city storm drain; municipal storm sewer systems; industrial storm water, such as from construction sites

Source: https://nptel.ac.in/content/storage2/courses/105101010/downloads/Lecture28.pdf

Water pollution- non point sources

- **Non–point source pollution (NPS)-** contamination that does not originate from a single discrete source.
- NPS pollution is the cumulative effect of small amounts of contaminants gathered from a large area.
- Pollutants will come from wide spread area
- They can’t be tracked to a single point or source

Examples: Soil erosion, chemical runoff, animal waste pollution

– leaching out of fertilizers/ nutrients agricultural lands.

– Nutrient runoff in storm water- agricultural field/ forest.

– Contaminated storm water washed off of parking lots, roads and highways called urban runoff

Source: https://nptel.ac.in/content/storage2/courses/105101010/downloads/Lecture28.pdf

Water Pollution – Specific Sources

- **Septic systems -** Use a large tank buried in the ground to contain and break down household sewage; Fats, oils, and grease as well as large waste particles, are stored and later pumped out of the holding tank; 40-60% source of concern for groundwater pollution & surface water pollution
- **Lagoons:** shallow holding pits into which wastes are pumped and treated; Water Quality Problems: Poorly constructed lagoons (leakage); lagoons built on high water table; Nitrates: most often found contaminant
- **Waste Disposal:** Underground or above ground disposal

Source: https://nptel.ac.in/content/storage2/courses/105101010/downloads/Lecture28.pdf

- Industrial liquid waste – treated/ untreated
- Solid waste - Land disposal of municipal and industrial solid waste – leaching
- Storage and Transport of Commercial Materials – storage tanks & spills
- Mining operations: Mines, Oil & gas- Acid mine drainage, Leaching of toxic metals, Wastewater generated
- Agricultural operations: Fertilizers; Pesticides
- Saline water intrusion

Source: https://nptel.ac.in/content/storage2/courses/105101010/downloads/Lecture28.pdf

Relative humidity

$$= \frac{\text{Amount of moisture present in the atmosphere at temp of } t^\circ C}{\text{saturation level of moisture at temp } t^\circ C} \times 100\%$$

$20^\circ C \rightarrow 80\%$

$20^\circ C \rightarrow x \ g/m^3$

$25^\circ C \rightarrow y$

$y > x$

$20^\circ C \rightarrow 80\%$ $\quad$ $15^\circ C \rightarrow 100\%$ $\quad$ dew

$30^\circ C \rightarrow 70\%$ $\quad$ $10^\circ C \rightarrow 100\%$

pH → 6.5 to 8.5

Color →

Taste →

Turbidity → 5 NTU

TDS → 100 - 1000 PPM

Cr, Pb, Cc

pH →

Color → gray, black

Turbidity

Total Suspended Solid

Total dissolved solid

TS

→ DO

BOD

COD

→ Microbols

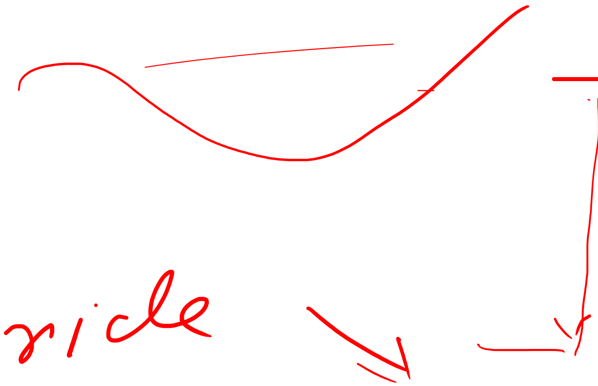
pathogens

→ MPN Test

70%

Arsenic

~~Flurodi~~ Fluoride

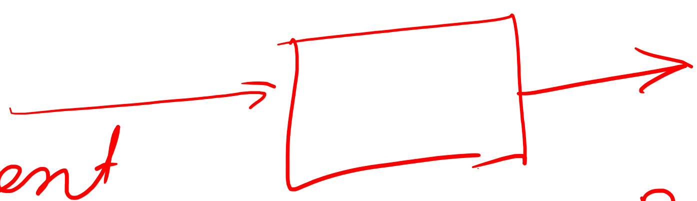


~~30 ft~~

100 ft

800 ft

Influent



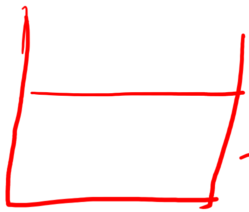
Effluent

BOD ⇒ less than 30 mg/l

COD ⇒ ~~100~~ mg/l

6.5 to 8.5

TSS



50ml → Whatman 41 filter paper → The retained TSS at 105°C for 24 hrs

5.6 gm → 5.7 gm

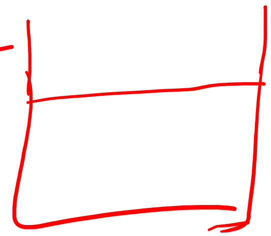
$$\frac{0.1\ \text{gm}}{50\ \text{ml}} \times \overset{20}{1000}\ \text{ml} = 2\ \text{gm/l}$$

$$= 2000\ \text{mg/l}$$

1 l of sample → ~~20~~ 2 g of Solid

→ 2 g/l

TDS



50 ml

put in hot air oven @105°C for 24 hrs

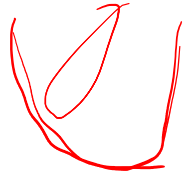
$W_1 = 200$ gm → Initial wt. of beaker

$W_2 = 201$ gm → Final " " "

Dissolved solids wt. = $W_2 - W_1 = 201 - 200$

$= 1$ gm

Conc = $\frac{1}{50} \times 1000 = 20$ gm/l

VS →  crucible $W_1 =$

$W_2 \to$ Crucible + ash

Muffle furnace

↓

540°C

for 30 minutes

ash → $W_2 - W_1$

→ 100.06 gm − 100 gm

Fixed ~~volatile~~ Solids wt. → 0.06 gm = 60 mg

50 ml → 60 mg of ~~VS~~ Fixed

$1\,l \to \frac{60}{\cancel{50}} \times \cancel{1000}^{20} = 1200\ mg/l$

volatile → 2000 − 1200 = 800 mg/l