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Er. Iswor Rawat
Engineer

Water Supply & Sanitary Engineering

General

→ Water is one of the most important substances on the earth.
→ All plant & animals must have water to survive.
→ Human can live without food for weeks but only 5-7 days without water.

Types of Water

① pure & Impure water

→ Water is Chemical Compound with Chemical formula H_2O.
→ The water does not contain any other substances then hydrogen & oxygen is called pure water.
→ The water contain other substances then hydrogen & oxygen such as minerals, salts, gases, microorganism etc called impure water.
→ pure water is not actually suitable for drinking purpose, because it lacks vital minerals required for human growth.
→ pure water is widely used for medical & laboratory purposes.
→ Water used for drinking purpose is impure water, but impurities not excessive.

② potable & Wholesome water

→ Water is safe for drinking by human & other animals is called potable wate
→ Wholesome water is fit to use for drinking, cooking, food preparation or washing without any potential danger to human helth by the requirements that includes limit on:

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→ Biological quality (including level of bacteria)
→ Chemical quality (including levels of metals, solvents & hydrocarbon)
→ Physical quality (including levels of color, taste & odour.

③ polluted & contaminated Water

→ The water contains excessive impurities such as minerals, salts, gasses, microorganisms etc is called polluted water.
→ The polluted water is not generaly clean & whole some.
→ polluted water not use for drinking.
→ The water contains microorganisms such as bacteria, virus, protozoa, worms etc is called contaminated water.
→ The contaminated water may look clean but contain microorganism of microscopic nature which not visible through naked eye.
→ The contaminated water is not potable & not used for drinking.

Objective of Water supply system

→ To supply safe, whole some & potable water to consumers.
→ To supply water in adequate quantity.
→ To make water easily available to the consumer.
→ To supply water affordable price.
→ To supply equitable water.
→ Easy to accessible.
→ To supply water to domesticated animals, industries & Commercial etc

Sources of water & it's selection.

→ primary sources of water supply is precipiation.
→ Rainfall is most important part of precipiation.

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[A] Surface Sources	[B] Sub-surface sources
→ River	→ Spring
→ Stream	→ Wells
→ Lakes	→ Infiltration galleries.
→ pond	→ Infiltration Wells.
→ Impounded reservoir	

[A] surface sources

→ Sources of water are available at the ground surface.

→ Quality & quantity of surface water depends on combination of climatic & geological factor.

① River

→ River is a natural channel which carries surface runoff by from its catchment or drainage basin.

→ It also carries ground water flow & runoff from melted snow.

→ River orginate in mountain where large no. of spring & stream combine together.

→ In the mountain quantity of water in river is smaa due to its catchment. But river moves fordword discharge in river increase due to increase catchment area.

② Stream

→ Streams are natural drainage channel found in mountainous regions.

→ Quantity of water in stream much less in compared to rivers.

→ It can used as sources of water supply in village or hilly area.

→ Quality of water in stream is normany good except water of first runof

③ Lake

→ Large natural depression or hollow formed in earth's surface which gets filled with water.

→ Generally found in mountain regions.

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→ Quantity of water available from lake depends upon: it's size, catchment area, annual rainfall etc.

④ Pond

→ Pond is a man made body of standing water smaller then lake.

→ Pond are formed by digging of ground & they are filled up with water in rainy season.

→ It contains many impurities.

⑤ Impounded Reservoir

→ Create a storage reservoir or an artificial lake by constructing a bund, weir or dam across the river.

→ Store the excess water during wet seasons.

→ Supply " " " " dry seasons.

Capacity Determination of Impounded Reservoir

ⓐ Analytical Method

→ Simple calculation using calculator.

→ Capacity of Impounded reservoir = Maxᵐ Cumulative surplus + Maximum Cumulative deficit − Total inflow + Total demand.

ⓑ Mass curve Method

→ plot between cumulative inflows in the reservoir with time.

→ Capacity depends on rate of inflow, losses, demand or outflow.

→ plotting of data in graph paper & smoothing of curve may not give accurate result.

Procedure

i) Find cumulative runoff value for period consider.

ii) " " demand " " " "

iii) plot cumulative value versus time period.

iv) Required storage capacity of the reservoir is the maxᵐ of the vertical intercept ordinates betⁿ the two tangents drawn to peak & trough consequently.

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B Sub-surface or Underground sources

→ Sources of water which exist below the ground surface.

→ Quality of underground water are generally good because of it's natural filtering cabability.

① Spring

→ spring is a natural outflow of groundwater.

→ Appears at the ground surface as a current or stream of flowing water.

Gravity spring → water flowing under hydrostatic pressure.

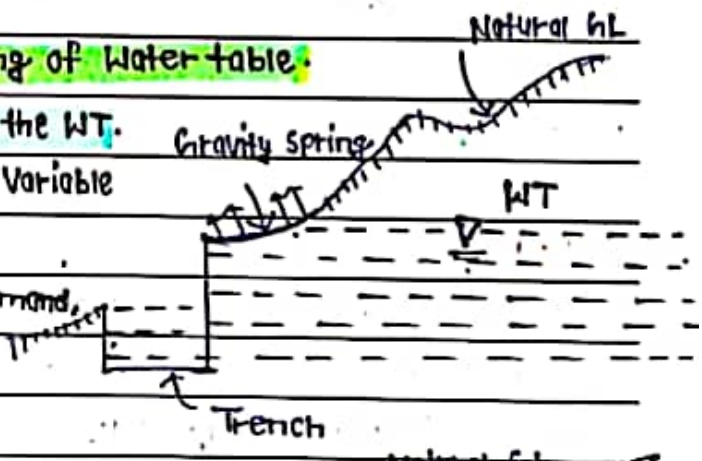
② Depression spring

→ Formed due to overflowing of water table.

→ Ground surface intersects the WT.

→ Flow from such spring are variable with rise or fall of water table.

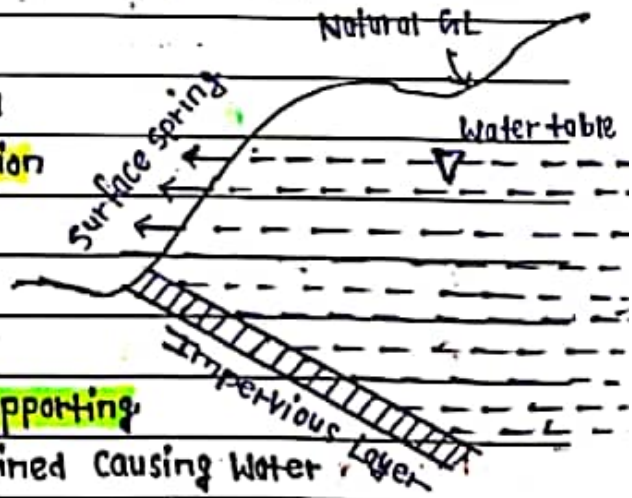
→ In order to meet water demand, deep trench may constructed near such spring.



③ Contact or Surface Spring

→ These spring are created by a permeable water bearing formation over laying a less permeable or impermeable formation that intersects the ground surface.

→ Impervious obstraction supporting underground storage becomes inclined causing water table to go up & get exposed to ground surface.



④ Artesian Spring

→ These spring results from release of water under pressure from Confined aquifers.

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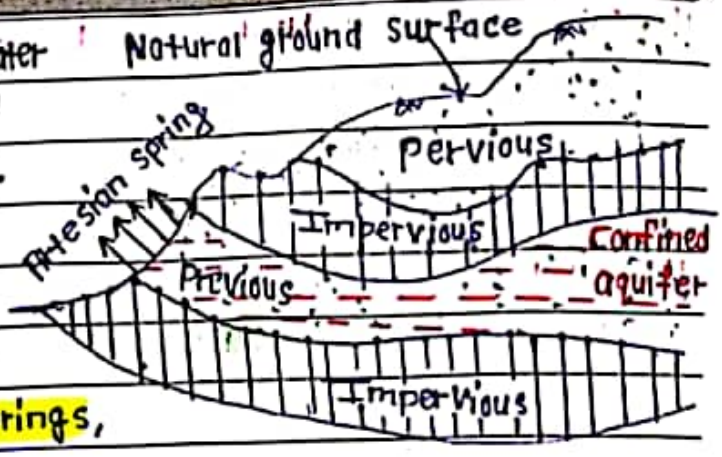
→ The amount of water available may be large, if Catchment area is large.



Non-Gravity spring

→ Include Volcanic springs, fissure springs.

→ These are also called hot spring & contain high minerals as well as sulphur.

→ Hot spring can not be used to supply water for domestic purpose.

② Well

→ Well is a hole or shaft, usually vertical, excavated in the ground for bringing groundwater to the surface.

Types ⓐ open or Dug Well

→ Which have Comparatively large diameter but low yields & are not very deep. → Usually Constructed by digging.

→ may be built of brick or stone masonry or precast concrete rings.

→ Diameter of open well = 1 – 10m

→ Depth of open well = 2 – 20m

→ Thickness of Well = 0.5 – 0.75m

→ Discharge = upto 5lps (liter per second)

ⓘ Shallow open Well	ⓘⓘ Deep open Well
→ Rest in top water bearing starta & drawn their supplies from surrounding materials	→ Rest on impervious starta. & drawn their supplies from permeable formation laying below the impervious starta through bore holes made in the

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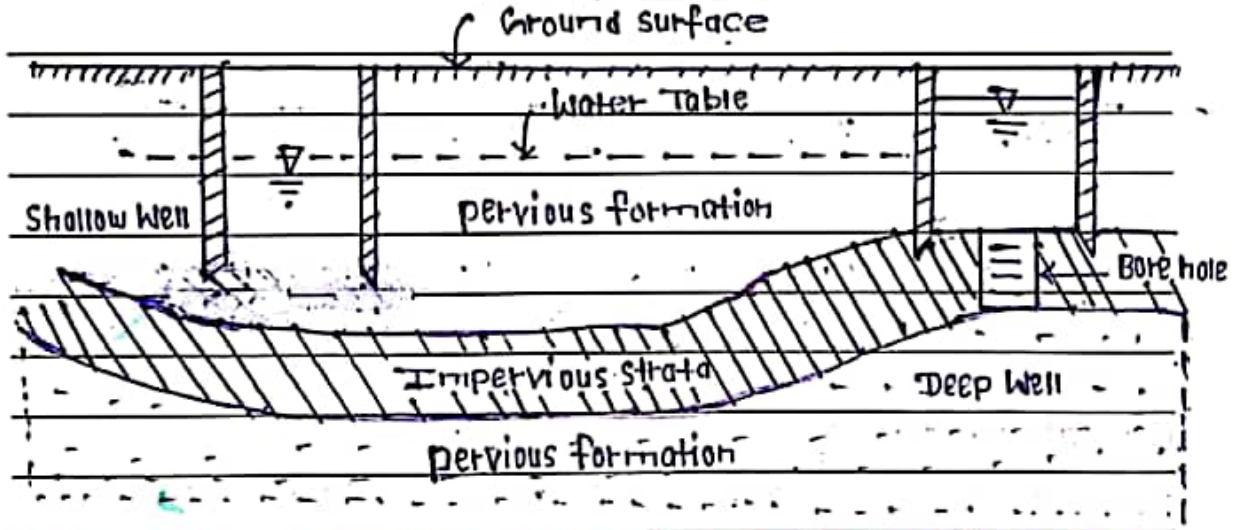
→ more chances of contamination	→ Less chance of contamination. but presence of minerals in high amount.
→ yield from shallow well is less & water is adequately available for single family.	→ yield from deep well is more & water is adequately available for community.
→ quantity of water available is uncertain due to large variation in groundwater table	→ quantity of water available is uniform since there is no fluctuation in water level.



Note: Shallow & Deep well are classified according to Discharge

→ Depth of shallow well may be more then deep well.

(b) Tube Well

→ Long pipe sunk into the ground intercepting one or more water bearing starta.

→ Comparatively less diameter.

→ may be classified ① Shallow tube well (30m depth) maximum
② Deep tube well (600m depth)

→ Further classified

(I) Strainer type tube well

→ if not stated, tube well means strainer type.

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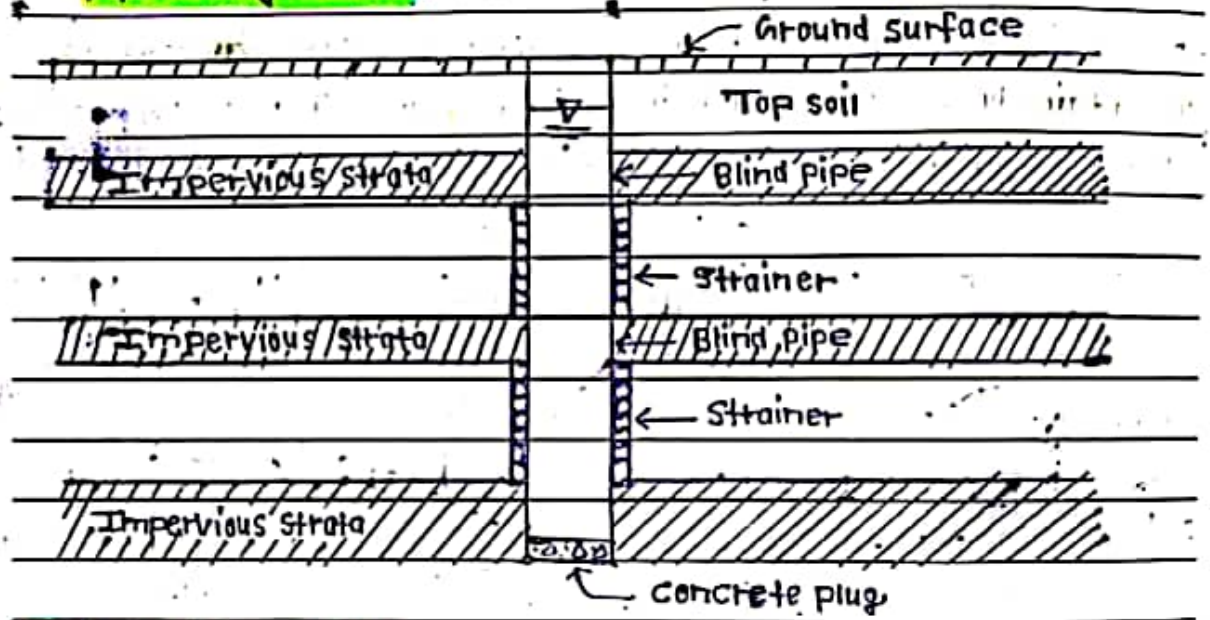
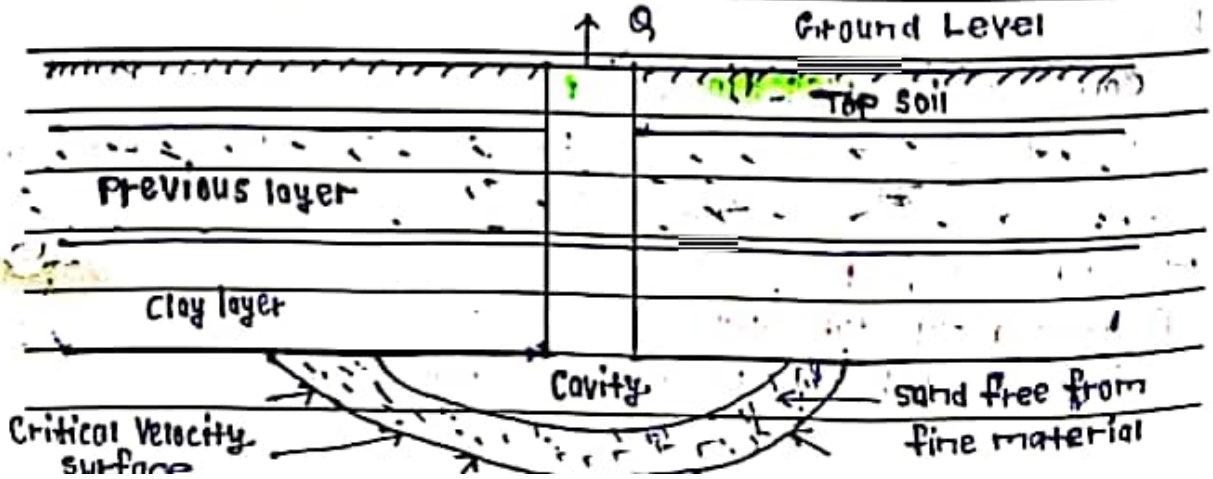
→ The strainer pipes & blind pipes are alternately placed.
→ Strainer consists of fine wire mesh wrapped round perforated pipe.
→ Size of openings of wire mesh = D_{60} to D_{70} of surrounding soil.
→ Mostly used in nepal.
→ Pipe having hole : Strainer / screen pipe. — kept at pervious layer.
→ Pipe having no hole : Blind pipe — kept at impervious layer.



(II) Cavity type tube well

→ The borehole is dug until it finds the previous layer of water.
→ pumping is done & Sandy water is withdrawn.
→ Cavity formation occurs at the sandy layer & thus, water enters the sand pore at critical velocity but less then this in the cavity.
→ Thus after sometimes clear water is obtained.



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(III) Slotted type tube well

→ This well is made at such places where sufficient depth of water bearing stratum is not available even at depth 80—100m.

→ Also suitable, strong roofing layer is not available for the construction of a cavity well.

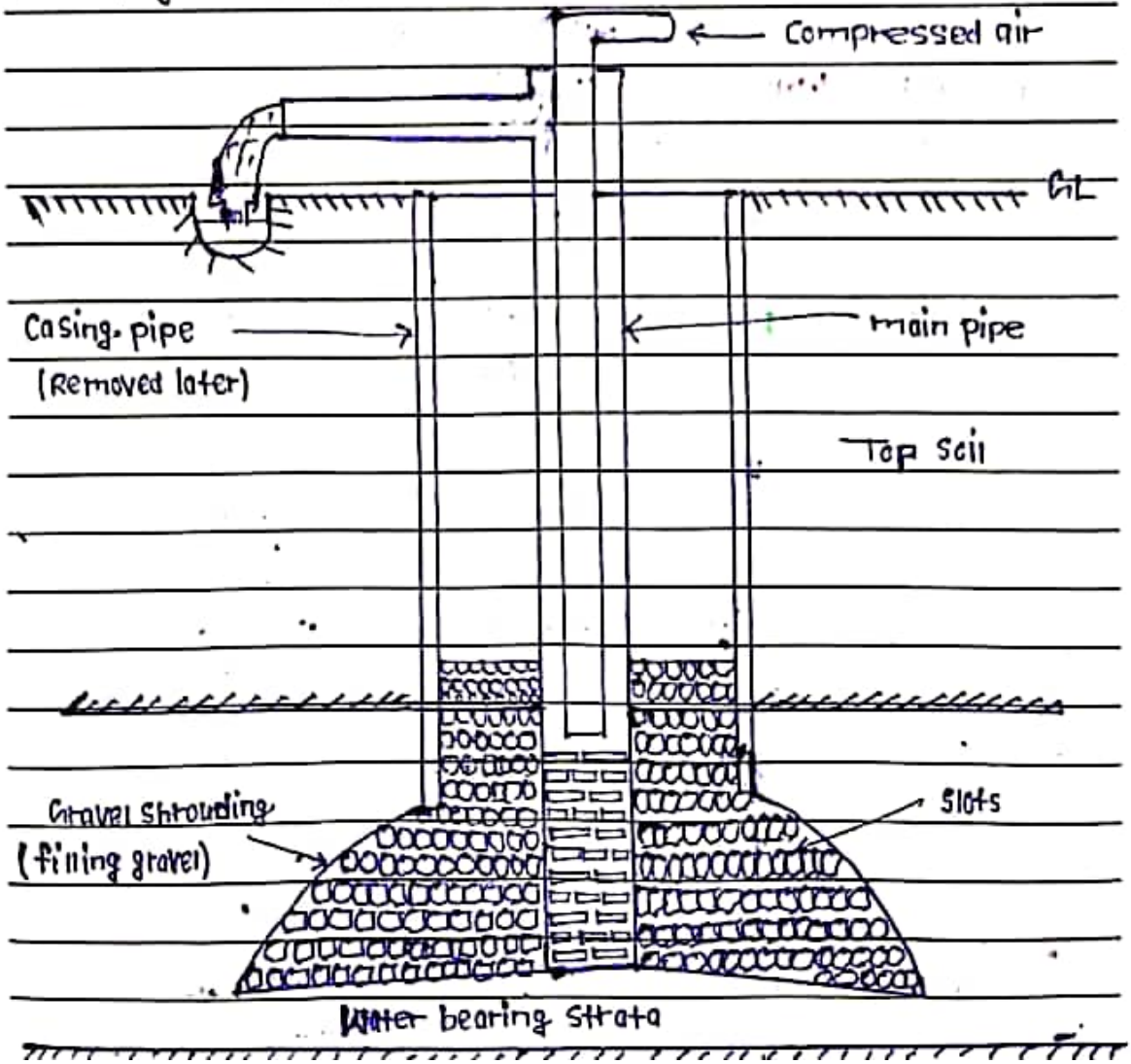
→ This well consists of a slotted wrought iron tube penetrate a highly previous confine aquifer.

→ Size of slots = 25mm × 3mm → Space = 10–12cm c/c.

→ Also called education pipe of 15cm dia^{m} is, then lower.

→ Gravel is then pour from top in the annular space left bet^{n} inside of the casing pipe & outside.

→ The gravel is filled for 3–4m higher then slotted pipe.



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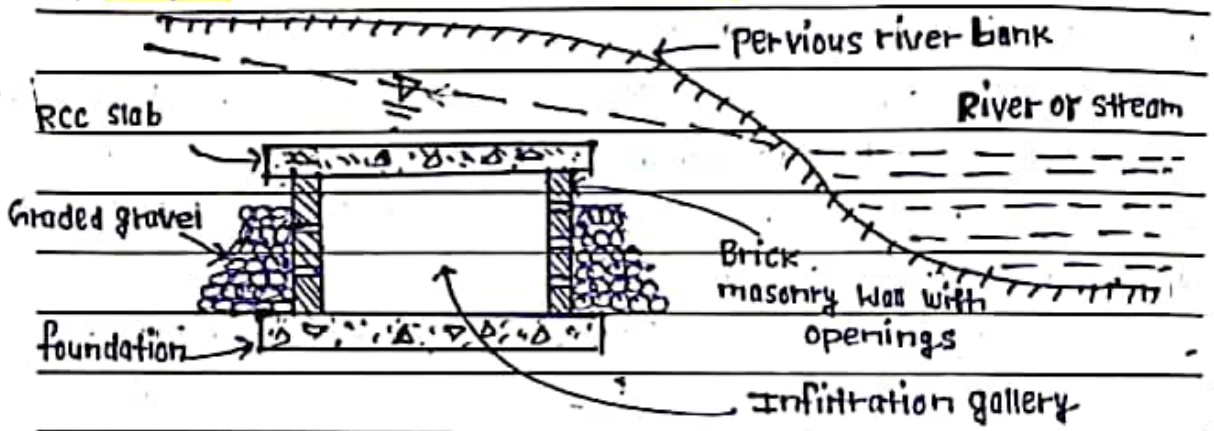
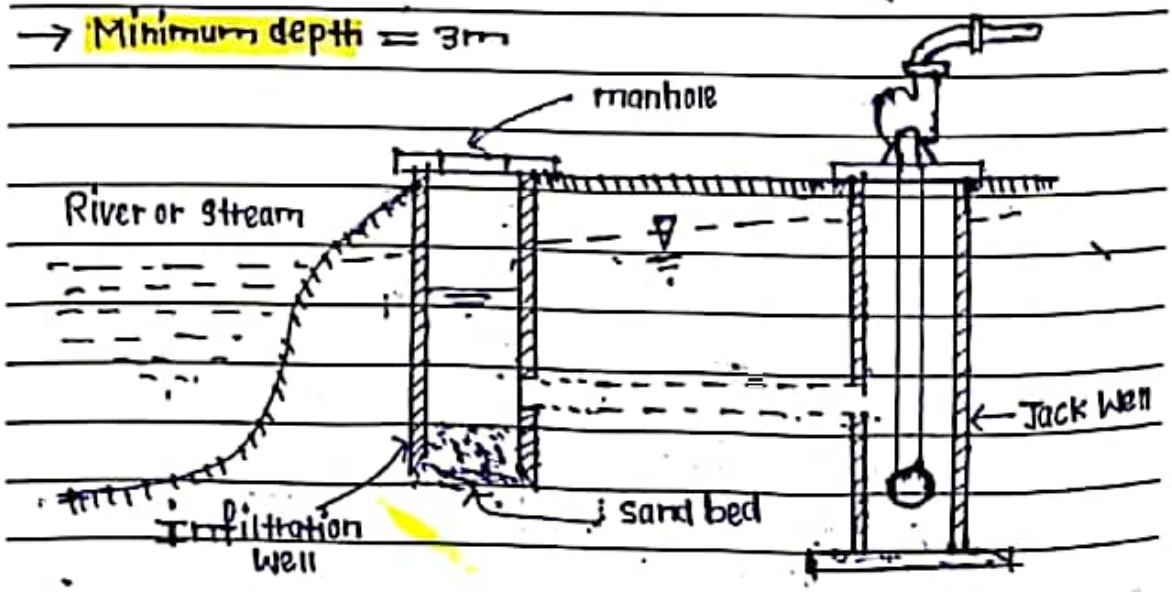
③ Infiltration gallery

→ Horizontal or nearly horizontal tunnel.
→ Usually rectangular in cross-section & having permeable boundar
→ Also known as horizontal Well.
→ Constructed along sides of river.
→ Depth = 3m – 10m → Slope = 1:300 – 1:500.



④ Infiltration Well

→ Constructed along banks of river.
→ Work on the same principle as infiltration gallery.
→ They are open at bottom & closed at top.
→ Two sets of Well are present. → Infiltration well (series)
→ Jack Well
→ Used as source of water for small community.
→ Minimum depth = 3m



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Technical Terms

① Aquifer

→ It is a water bearing stratum.

→ Aquifer is a gelogical formation that contains sufficient permeable material which permits storage as well as transmission of wate

→ Sand & gravel are example of formation which serve as aquife

Types ⓐ Confined aquifer

→ Ground water is confined under pressure greater then atmospheri by overlaying relatively impermeable strata.

→ Also known as artesian aquifer. → quality : good.

→ Discharge : more → Not affected by season.

ⓑ Unconfined aquifer

→ Water table is serve as the upper surface of zone of saturatio

→ Discharge : less → It is Temporary.

→ Also known as free aquifer, or pressure aquifer.

② Aquiclude

→ Aquiclud is a gelogical formation of relatively impermeable materia which permits storage of water but not capable of transmitting water in sufficient quantity. → e.g. Clay layer.

③ Aquifuge

→ Aquifuge is a gelogical formation of relatively impermeable material which neither contains nor transmit water.

→ e.g. rock, solid granite.

④ Aquifard

→ It is a type of water bearing stratum having capacity of layer which can transfor water from aquifer to aquiclude. (5)

→ e.g. Silty clay layer.

⑤ Inverted Cone of depression

→ A line of depressed water table in well during discharge.

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⑥ Circle of influence

→ The base of cone which lies over the orginal water table.

⑦ Draw down curve

→ Depression with orginal water table & curve showing the draw down in well.

⑧ priming

→ process of removing trapped air from pump & filling it completely with water.

⑨ PH Value

→ pH is measure of how acid or base the water is.

→ pH measure the concentration of hydrogen ions (H^+).

→ pH scale range = 0 – 14 → pH of 7 = Neutral

→ pH below 7 = acidic → pH above 7 = basic

→ It is measured by pH meter, litmus paper.

→ $pH = -\log_{10} H^+$

* if pH < 7 Acidic water, pH = 7 pure water, pH > 7 alkaline water

Selection of Water Source

① Location of Source

→ Water can conveyed through gravity from the sources to consumer area without pumping.

→ Location of source should be near as possible from supply community. this will reduce pipe length & minimize the cost.

→ If both surface & ground sources are available in community use of surface sources is perferable.

② Quality of Water

→ Safe, wholesome & free from pollution of any kind.

→ If safe water is not available is should be chiefly treated.

→ The treatment of water should be avoided as far as

possible by selecting the sources with good water quality.

③ Quantity :

→ During driest period should be sufficient to catch the deman of community such as domestic, industrial, Commercial, Public etc

④ Cost

→ Cost for water supply system should be minimum so that water can be supplied to the consumers at affordable price.

→ Cost of water supply system depends on many factor such a system of supply, elevation of Community, distance etc.

⑤ Continuity & Reliability :

→ The source must be selected to supply water continuously to the consumers & source need to reliable as well.

Gravity Water Supply System

→ Natural water sources are not always in a convenient place for collecting water. gravity water system use gravity to transport water from the sources to the user through a pipe network.

Design period

→ Future period or number of year for which a provision is made while planning & designing a water supply project is design.

Base period

→ It is the period required for survey, design & construction of water supply system. It is usually 2–3 years is adopted.

2075	2–3 year	2078	20 years	2098
survey year	base period	base year	design period	design years

Note :

Base year = survey year + base period

Design year = base year + design period

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Community	Base period	Design period
Rural Water supply system With high population growth rate. ($r > 2\%$)	2–3 year	15 year
Rural Water supply system With low population growth rate ($r < 2\%$)	2–3 year	20 year
Urban Water supply system	2–3 year	30 year

Selection Basic of Design period

① Population growth rate → Shorter design period is consider if the population growth rate is high & Vice–Versa.

② Development of community → Development of community the population growth will be high & shorter design period selected.

③ Useful life of compenent structure → The design period should not exceed the useful life of the component structure.

④ Availability of fund → Shorter design period should be selected when limited fund are available & Vice–Versa.

⑤ Availability of Water at Source → if the water available at sources is limited, then design period is short.

Determination of Daily Water Demand

Per Capita Water demand → The average quantity of water consumption or water demand for various purpose per person per day is known as per capita water demand.

→ It is usually expressed in lpcd (liter per capita per day)

→ Mathematically, $\text{per capita demand} = \frac{Q}{P \times 365}$

Where; Q = Total quantity of water required per year.

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Types of Water Demand

① Domestic Demand

→ Use in private, residences, apartment house etc for drinking, cooking, bathing, washing, gardening & sanitary purpose.
→ Rural area served by public stand post = 45 lpcd. (Rural)
→ Partly plumbed house = 65 lpcd (semi-urban)
→ Fully plumbed house = 112 lpcd (Fully urban)

② Livestock Demand

→ Water required for domestic animal.
→ Big animal (Buffalo, Cow, horse etc) = 45 lit/animal/day
→ Small animal (goat, pig, sheep etc) = 20 lit/animal/day
→ Poultry (Birds), ducks, Chicken etc = 20 lit/100 birds/day
→ Livestock demand ≯ 20% of domestic demand.
→ Consider in rural communities only.

③ Institutional & Commercial Demand

→ Water required for educational institutions, offices, hotels, hospital, resturants etc.
→ School/Collage
  → Day Scholar = 10 lpcd
  → Boarders = 65 lpcd
→ Hospital = 500 lit/bed/day
→ Health post (Without toilet) = 1000 lit/day
→ Health post (With toilet) = 2500 – 3000 lit/day
→ Hotel (With bed) = 200 lit/bed/day
→ Hotel (Without bed) = 500 – 1000 lit/day.
→ Resturant & tea stalls = 500 – 100 lit/day
→ Office = 500 – 1000 lit/day
→ Consider in both urban & rural Communities.
→ Minimum Water demand is 65 % of total demand.

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④ Industrial Demand

→ Considered only for urban area.

→ 20 – 25 % of total demand.

⑤ Public / municipal Demand

→ Used for watering of public park or garden, road washing, cleanning sewer, large market etc.

→ 5 – 10 % of total demand.

⑥ Fire Demand

→ Required for fire fighting.

→ Determine by various emprical formula

① DWSS (Department of Water supply & Sanitation)

$Q = 100\sqrt{P}$ Where, P = population in thousands

→ ≠ 1 lpcd. Q = quantity of water in lit/min

② Buston's Formula $Q = 5663\sqrt{P}$

③ Kuichling's Formula $Q = 3182\sqrt{P}$

④ Freemans formula $Q = 1136\left[\frac{P}{5} + 10\right]$

⑦ Loss & Wastage

→ Considered for misconnection, leakages etc.

→ upto 15 % of total water demand.

→ According to NWSC (Nepal Water Supply Cooporation) = 35%.

Total Water Demand = DD + LD + CD + ID + PD + FD + L&W

Variation in Demand of Water

① Seasonal Variation

→ The rate of demand of water varies from season to season.

→ The rate of demand in summer is more.

→ In India, seasonal peak factor = 1.4

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→ But in nepal, seasonal variation is neglected.

∴ seasonal peck factor = 1.

→ Maxm seasonal demand = seasonal peak factor X Annual average demand

② Daily Variation

→ Varies from day to day.

→ Depend on climate, holiday & festival day etc.

→ In india, daily peak factor = 1.8

→ In nepal, daily peak factor = 2.1

→ Maxm daily demand = daily peak factor X Annual average demand

③ Hourly Variation

→ Varies from hour to hour of the day.

→ In india, hourly peak factor = 1.5.

→ In nepal, hourly peak factor = 2-4.

Peak Factor → Ratio of maximum or peak demand of water to average annual demand of water.

→ Design demand = peak factor X average demand

→ peak factor = seasonal peak factor X daily peak factor X Hourly peak factor

→ Peak factor = 2 for Continuous system.

= 4-6 for intermittent system.

Reservoir → It is a tank used to store water. Types → ① Clear water reservoir
→ ② Distribution reservoir

Determination of Storage tank Capacity

① Balancing or equalizing reserve

→ Quantity of water required is stored in tank for balancing the variable demand in distribution system.

→ It is calculated by analytical method & mass curve which is explained in impended; reservoir capacity determination.

② Breakdown reserve

→ Breakdown may takes place in pumps or driving system.

→ 25% of total capacity of reservoir.

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→ Some Water is required to stored which may be utilized for breakdown period. like, pipe failure, electricity shut down et

→ ≯ 25 % of total storage.

③ Fire reserve

→ Water stored in distribution system for fire fighting purpose

$R = [F-P] \times T$ → 1-4 lit/person/day

Where; R = Reserve storage in liter.

F = Fire demand in lit/min

P = Reserve fire pumping capacity in lit/min

T = Duration of fire in min.

Capacity of storage Reservoir = Blancing reserve + Breakdown reserve + Fire reserve

Selection of pipe Materials

① Structural strength → pipe material should be strong enough to bear both internal & external pressure.

② Durability → pipe material should be durable.

③ Resistance to Corrosion → Natural Water may be acidic or basic or may contain highly corrosive chemical.

→ pipe material should be capable of offering resistanes to Corrosion

④ Resistance to abrasion → Water may contain suspended solid which may erode the internal surface.

→ So, pipe material should possess enough resistance to abrasion.

⑤ Impervioushess → The admission of waste water & ground water into the pipe is prevented.

⑥ Smoothness → pipe material should be smooth, min" head loss.

⑦ Weight → Should be minimum, so easily handled & transport.

⑧ Easy to join → easy to join different pipe & fittings.

⑨ Cost → Cost of pipe including handling, transportion & installation is less.

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Type of pipe Material

① Cast Iron pipe

→ highly durable.
→ longest useful life = 100 year
→ Resist high internal & external pressure.
→ highly resistances to corrosion.
→ easy to join. → length : 3-6m

Disadvantages

→ Heavy & difficult to handel & transport
→ Cost of transportation is high.
→ Water carrying capacity of pipe decrease with time.

② Ductile Iron pipe

→ Lighter then cast iron.
→ Greater strength then C.I.
→ Greater impact resistance then CI.
→ Greater ductility then CI.
→ Easy to joining.

Disadvantages

→ Require internal & external protection system.
→ Similar rate of corrosion to Cast iron & Steel pipe.

③ Steel pipe

→ Light in weight.
→ Easily handeled & transported.
→ Very strong to withstand internal pressure
→ Cheap & avilable in long length.

Disadvantages

→ Can not withstand external pressure such as earth filling, traffic.
→ Maintenance cost is high.
→ Pipe are likely to deforms it shape.
→ pipe are likely to rusted.

④ Cement Concrete Pipe

→ Either pcc or RCC. → Under Water
→ Suitable for external pressure.
→ **Pcc** : used for head upto 15m
→ **Rcc** : used for head upto 60m
→ Maintenances cost are very low.
→ Pipes of durable. → life span = 75 yr.
→ highly resistance to corrosion.
~~→ Length = 2.5m~~

Disadvantages

→ pcc can not with stand high internal pressure & liable to tension crack.
→ precast pipe are heavy.
→ difficult to handel & transport.
→ difficult to make service connection.
→ Leakage in pipes due to porosity & shrinkage crack.

Note

→ Presstressed concrete pipe are also known as **hume pipe**. > 60m

⑤ AC pipe (Asbestos cement)

→ Made of cement & asbestos fibre.

→ Used to drainoff rain water from roof.

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⑥ GI pipe (Galvanized iron pipe)

→ These are wrough iron & mild steel

→ Coated with zinc.

→ Used for house plumbing, water supply inside the building.

→ Cheap, light.

→ Easy to join.

→ Used when pressure head exceeds 100m

→ Available in 3 grades

Disadvantages

→ High cost, dia^{m} more then 80

→ liable to corrosion.

→ relativeiy less durable.

→ Smoothness of these pipes decrease with time.

↳ Life span = 20 year → Used when pressure head exceed = 100

⑦ PVC pipe (polyVinyl Chloride) Plastic pipe < PVC / HDPE

→ Light, non-corrosive, cheap etc. → Life span = 50 year

* UPVC : Unchlorinated PVC, used for cold water.

* PVC : plasticized pipe, used for water upto 60°c.

* CPVC : Chlorinated PVC, used for hot water upto 120°c.

⑧ HDPE pipe (High density poly ethylene) ↳ used for Wiring, Waste Wat

→ Used for gravity supply scheme.

→ Made from ethylene.

→ Cheap, flexible.

→ Eaasy to joins without fitting.

→ Very smooth.

→ High impact strength.

→ Life span = 50 years.

→ Available in different series.

→ Black in colour.

Disadvantages

→ poor temperature capability & not good for carrying hot water.

→ Less resistance to weathering.

→ High thermal expansion.

→ Made of softer material & easy to make illegal connection.

→ Generally used in rural water supply pipe line.

Laying of pipe line

Depth = 90cm more then external dia^{m} of pipe.

Width = 30-45cm " " " "

Extra 15cm is provided in fitting of joint

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S.N	Types of Pipe	Property	Identification Colour strip	Test pressure (Kg/cm^2)	Allowable Working pressure (Kg/cm^2)	Resist Pressure Head resisted (m)
1		Heavy	Red			
2	GI	Medium	Blue			
3		Light	Yellow			
4	I	2 Kg/cm^2	Brown	2	1.5	20
5	II	2.5 Kg/cm^2	Red	2.5	1.875	25
6	HDPE III	4 Kg/cm^2	Blue	4	3	40
7	IV	6 Kg/cm^2	Green	6	4.5	60
8	V	10 Kg/cm^2	Yellow	10	7.5	100

Pipes	Joints
① CI pipe	Spigot, socket, thread, flanged joint
② Steel pipe	Welding & riveting joint.
③ Concrete pipe	Collar joint
④ GI pipe	Socket Screwed joint
⑤ HDPE pipe	butt Welding
⑥ A.C. pipe	Collar & Simplex joint
⑦ Copper pipe	Screwed joint
⑧ Lead pipe	Wiped joint
⑨ plastic pipe	Solvent Welding
⑩ Asbestos pipe	ring tile Coupling
⑪ pcc pipe ⓐ Small dia.	Spigot & Socket joint
ⓑ Large dia.	ogee & Collar joint
⑫ Where Chance of settlement	flexible joint

Valve

→ Valve is a mechanical device that controls the flow & pressure of fluid within a system.

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Valves	Functions
① Sluice / Gate Valve	→ To control & regulate of flow.
② Check / Reflux Valve	→ Uni-directional flow. → prevent backflow
③ Air relief Valve	→ Summit & down stream side
	→ To release air.
④ Scour / Washout Valve	→ Use to drain off water from pipe after
	Closing the supply. → provided at low point.
⑤ Blowoff / drain Valve	→ To blow off dirty material in pipeline.
	→ Used in Depression & dead end.
⑥ Angle Valve	→ plumbing below wash basin
⑦ Foot Valve	→ Bottom of suction pipe, to prevent priming.
⑧ Float Valve	→ Used in Water tank
	→ Maintain constant water level & prevent overflow
⑨ Globe Valve	→ main line, control uni-directional flow
⑩ pressure relief Valve	→ Up stream side, for safety against high pressure.
⑪ Bib Cock / tap	→ fitted horizontally to pipe in kitchen, bath
	→ Obtain water from water supply & storage tank

Pump

→ Pump is a mechanical device that moves fluids, from one place to another place by mechanical acting.

Pumps	Functions
① Air lift pump	→ Suitable for sewage pumping.
② Booster pump	→ Used to increase pressure.
③ Centrifuga pump	→ Suitable for water & sewage pumping
	in large quantity.
④ Impulse / hydraulic	→ Special type of pump.
ram	→ Used to, where water head is high &
	small quantity of water is to be lifted.

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⑤ Pneumatic ejector	→ Suitable for small quantity of sewage pumping.
⑥ Puisometer pump	→ Used for Concreting.
⑧ Reciprocating pump	→ Suitable only for water but not for sewage.
⑨ Rotary pump	→ Not suitable for liquid containing suspended matter.
	→ It doesn't require priming.
	→ Used in petrol pump to deliver fuel.
⑩ Submersible pump	→ Designed & constructed for underwater pumping applications
⑪ Treadle pump	→ Operate by feet & not require any energy.
⑫ Trash Water pump	→ It are normally self-priming centifugal pump
	→ Used for dewatering at mines, Construction sites.

Distribution System

① Gravity System → Sufficient head available & flow of water under gravity
② Pumping System → " " not available & " " " " --pressure
③ Dual System → It is combination of both.

Components of Gravity Water supply system

① Intake
② Collection Chamber
③ Sedimentation tank
④ Storage tank
⑤ BPT
⑥ Interruption chamber
⑦ Distribution Chamber
⑧ Pipe line.
⑨ Suspender Crossing.
⑩ Stand post.

Factor Affecting Water Demand

① Climate Condition
② Size of community.
③ Living Standard of people
④ Industrial & Commercial activities.
⑤ Cost, Sanitation & distribution System.

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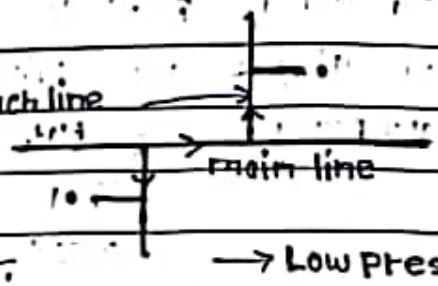
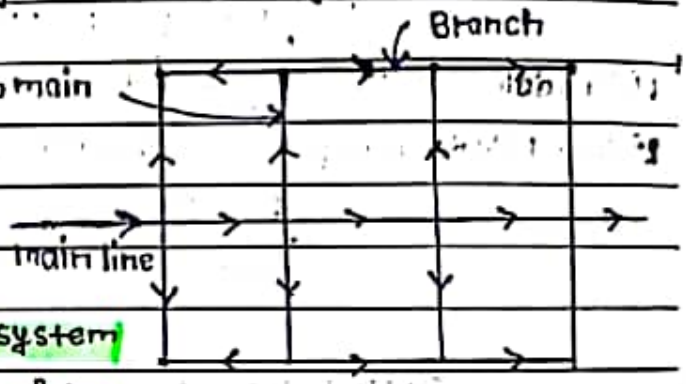
Layout of Distribution System

① Dead End / Tree system



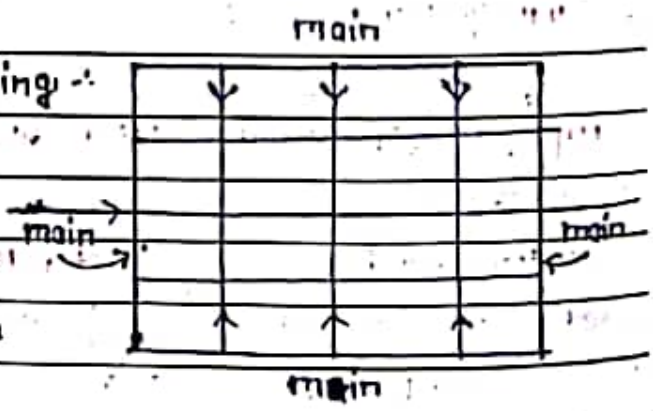
→ One main line & branches lines off from both side.
→ Calculation of discharge is easy.
→ Chances of stagnation of water. → Low pressure.
→ Difficulty in repair. → Not available for fire demand.
→ Suitable for haphazardly developing city. like; Kathamandu's

② Grid Iron system



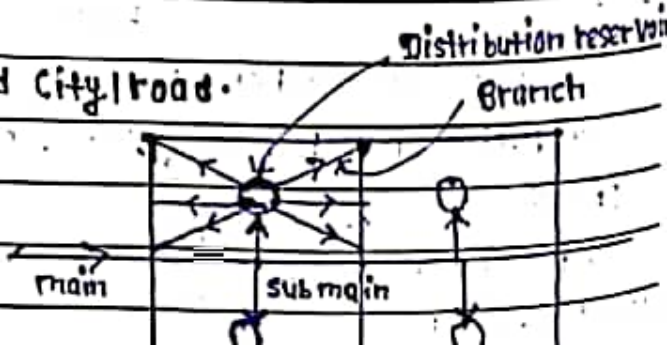
→ main, sub-main & branches in ⊥ direction.
→ No dead end.
→ Calculation of discharge is difficult. → Interlaced system
→ No chance of stagnation of water.
→ Easy to repairs. → Water available at high pressure.
→ Suitable for well planned city with rectangular pattern of road.

③ Circular / Ring system



→ The supply mains form a ring around the area.
→ Calculation of discharge is difficult.
→ No chance of stagnation of water.
→ Easy to repair.
→ Suitable for well planned city/road.

④ Radial System



→ Suitable for radially planned roads.

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Pipe line design & Hydraulic grade line.

The design of pipe line involves the determination of size of pipe which involves diameter & thickness.

1. **Hydraulic design** : Diam of pipe calculate.
2. **Structural design** : Thickness of pipe to with stand internal & extern pressure.

→ In hydraulic design, size of pipe may be determined by two equation.

① Continuity Equation

$Q = A \times V$

$A_1V_1 = A_2V_2$

Where; Q = discharg through pipe (m^3/s)

A = cross-sectional area of pipe = $\frac{\pi d^2}{4}$

V = mean velocity in pipe (m/s).

② Bernoulli's Equation

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + H_f$$

Where; P = pressure at the Consider section.

V = Velocity of Water in the section.

z = Elevation of Consider Section from references datum.

H_f = Head loss through the pipe length.

Head loss Can be determined by following formula

③ Manning's Formula

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$H_f = \frac{10.294 n^2 L Q^2}{d^{16/3}}$$

Where; V = Velocity of flow

n = Mannings constan

S = Slope of pipe

R = Hydraulic radius

L = Length of pipe.

④ Darcy's Weisbach Formula

$$H_f = \frac{fLV^2}{2gd}$$

Where; f = frictional factor

L = length of pipe

V = mean velocity, in pipe.

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© Hazen Williams Formula :

$$V = 0.85 C R^{0.63} S^{0.54}$$

$$H_f = \frac{10.68 L}{d^{4.87}} \left(\frac{Q}{C}\right)^{1.852}$$

Where; C = roughness coefficient
R = Hydraulic mean depth
S = slope of energy grade line.

Design Criteria of pipe — Recommended

① Velocity — Minimum velocity = 0.3 m/s
Maximum velocity = 3 m/s
For untreated water, minimum velocity = 0.6 m/s.

② Pressure — Residual head

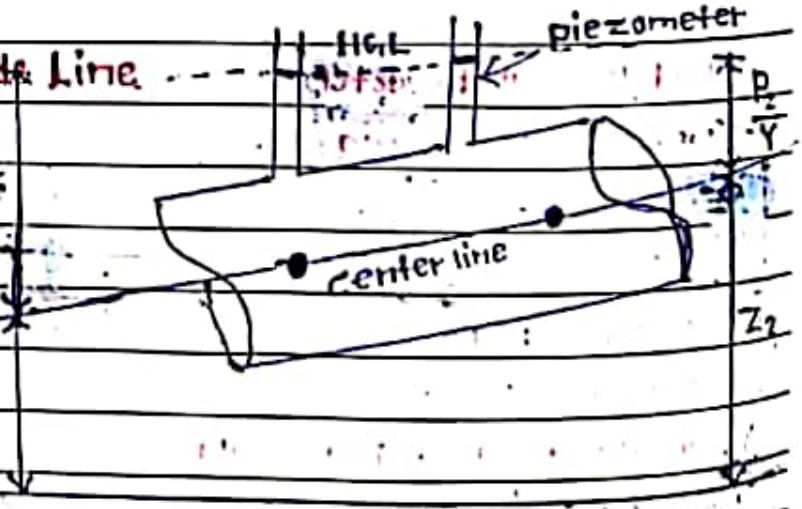
→ For system with private connection, minimum pressure = 15m
→ " " without " " " " = 5m
→ At public stand post, desirable pressure = 15m
→ " " " , absolute minimum pressure = 5m.
→ " " " , Maximum pressure = 55m.

③ Pipe size

→ pipe diameter in mm : 15, 20, 25, 32, 40, 50, 65, 80, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400, 2600, 2800 & 3000.

Hydraulic grade Line

→ HGL is the line joining all the piezometric heads.
→ In pipe flow, HGL (except syphon) is always above center of pipe.



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National Water Supply Standard; 2062

Concentration

S.N	Parameters	Unit	Max^{m} Conc. limit	Remarks
1.	Turbidity (measure by turbiditymeter)	NTU	5 (10)	
2.	Temperature	^{o}C	—	
3.	Taste	—	Unobjectionable	physical
4.	Odour	—	"	Test
5.	Colour (measured by tintometer)	TCU	5(15)	
6.	Electrical conductivity	MC/sm	1500	
7.	PH	—	6.5–8.5	
8.	Iron	PPM	0.3(3)	
9.	Manganese	PPM	0.2	
10.	Arsenic	"	0.05	
11.	Cadmium	"	0.003	
12.	Chromium	"	0.05	
13.	Cyanide	"	0.07	Chemical
14.	Fluoride	"	0.5–1.5	Test
15.	Lead	"	0.01	
16.	Ammonia	"	1.5	
17.	Chloride	"	250	
18.	Sulphate	"	250	
19.	Nitrate	"	50	
20.	Copper	"	1	
21.	Total hardness	"	500	
22.	Calcium	"	200	
23.	Zinc	"	3	
24.	Mercury	"	0.001	
25.	Aluminium	"	0.2	
26.	Residual Chloride	"	0.1–0.2	
27.	Total dissolved solids	"	1000	
28.	E-Coli	MPN/100 ml	0	Biological
29.	Total coliform		0 (95% Sample)	Test

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Quality of Water

Impurities in Water

① Suspended Impurities

→ Size : 0.1 — 0.001 mm.

→ Remain in suspension (eg; Clay, silt, oils, fungi etc).

→ It cause turbidity & it is measure in term of turbidity.

Note : Turbidity → Degree of clarity in water caused by suspended matter.

→ Turbidity ↑ = affect photosynthetics (scattaed light)

→ Turbidity is removed by Coagulation & filtration.

② Colloidal Impurities

→ Size : 10^{-3} — 10^{-6} mm.

→ Small, non-visible with naked eye, motion.

→ It cause color in water & measure by color test.

→ Sources : Silica, iron oxide, alumina, bacteria etc.

③ Dissolved Impurities

→ Size : 10^{-6} — 10^{-9} mm.

→ It is soluble in water.

→ It cause bad test, hardness & alkalinity.

→ It is measured by PPM (parts per minion) or mg/l.

→ Sources : Organic & inorganic solids, decay products of Vegetation.

Classification based on Characterstics

① Physical impurities → temp, color, taste, odour, turbudity etc.

② Chemical " → pH value, hardness softness dissolved solids e

③ Biological " → pathogenic & non-pathogenic bacteria.

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Water Treatment

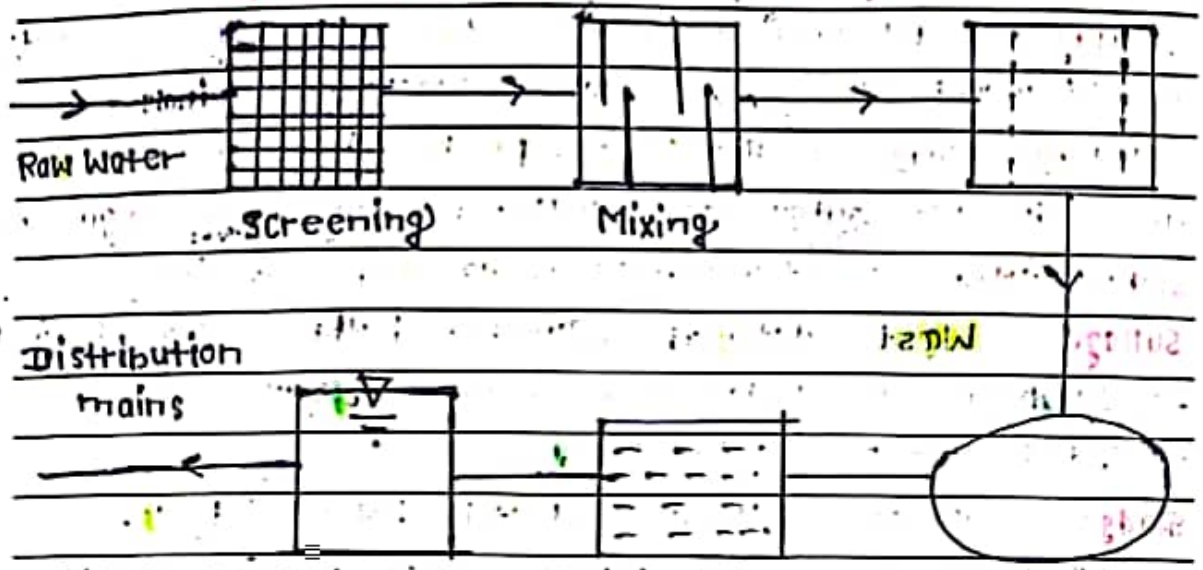

fig ; Water treatment

Design of Sedimention Tank

* Detention time → The theoretical time in which water pass from entry to exit of tank.

Design Criteria

① Detention time = (4–8) hr — plain sedimentation.
= (1–4) hr — Sedimentation with Coagulation.

② Length / Width = 3–5m

③ Depth ≤ 3.5m

④ Free board = (0.1–1)m, generally (0.3–0.5)m.

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Sanitary Engineering (Technical Terms)

Sewage → All kind of liquids waste comes from community.
→ It include storm water, sullage, waste from urinals etc.

Sanitary Sewage → The sewage produce during dry weather flow & does not contain storm water is called Sanitary engineering.

Storm Water → It includes rain water from locality.

Sullage → Waste water from kitchen, bathroom, wash basin etc
→ It does not include human excreta, urine.
→ It does not produce bad smell.

Sludge → Solid material deposited at the bottom of tank.
→ Which is in semi-solid condition. → But not from toilets.

Refuse → All kind of wastes.

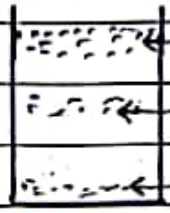
Garbage	Rubbish
→ Organic material (decomposed)	→ Inorganic material (non-decomposed)
→ Waste food, vegetable, grass etc.	→ Furniture, plastic, glass etc.

Night soil → Human excreta.

Excreta → Useless matter elimininated from human & animal body. eg; urine, fecal (मल), Sweat (पसीना) etc.

Scum → Upper most part of specific tank.

Effluent → Middle " " " "



Sewer → Sewer is a Circular pipe used to carry sewage & deliver to suitable point.

Cowl → It is provided at top of Ventilation pipe of sewer to prevent entering of bird inside & making nest.

Ventilation pipe → The pipe, which provides a safe outlet into the atmosphere for the foul gases in the drain or sewer.

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Sewerage System

→ Sewerage system are entire system for collecting & delivering sewage to a disposal point.

Types ① Separate system

→ Two set of sewers are provided, one for sanitary sewage & anothe for storm water. → Suitable for heavy rainfall for short time.

→ Circular shape.

Advantages	Disadvantages
→ Sewage is a uniform characttristics.	→ Pipe laying is difficult.
→ Storm water is not unnecessarily polluted.	→ maintenances cost is high.
→ Treatment cost is less.	→ Strength of sewage is high.
→ No risk of overflow of sanitary sewage.	→ Risk of entry of storm sewag
→ Storm sewage conveyed open drain, Cheaper.	to sanitary sewage during heavy
→ Cheaper if puming is required.	rain.

② Combined system

→ One set of sewer provided, only one sewer to carry both sanitary sewage & storm water. → Suitable for less reinfall area. → Egg shape.

Advantages	Disadvantages
→ House plumbing is easy & economical.	→ Overflow during heavy rain.
→ Strength of sewage reduce.	→ Storm water is unnecessarily polluted
→ Self cleaning velocity.	→ Silting problem may rise during
→ large size of sewer.	dry weather flow.
	→ Uneconomical if pumping require
	due to large quantity of sewage.

③ Partialy separate system

→ One set of sewer : Carries sanitary & industrial sewage & storm water from building.

→ Another sewer : Carries storm water from road, pavements etc.

→ Suitable for rainfall is throughout the year.

Note : Sewer used in Nepal → Combined system.

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Colour of sewage	Fresh sewage	Septic sewage	Stale sewage
	Grey	Blue	Black

Quantity of sanitary sewage

→ It is the sum of domestic & industrial sewage.
→ It is also known as dry weather flow (DWF).
→ flow available in non-rainfall time.
→ quantity of sanitary sewaage = population × peak factor × (70-90) % of rate of water supply.

Where; peak factor = 2-4

Factor Affecting the sanitary sewage

→ population → Type of area served.
→ Rate of Water supply → Infiltration & percolations.

Quantity of storm Water Sewage:

→ Empirical formula method (for large area)
→ Rational Method

→ Waste Water produced rain-water.
→ It is also known as Wet Weather flow (WWF).
→ $Q_{storm} = \frac{CIA}{360}$ m^3/s

Where; C = Coefficient of run-off $= \frac{C_1a_1 + C_2a_2 + \ldots + C_na_n}{a_1 + a_2 + \ldots + a_n}$

I = Intensity of rainfall (mm/hr).

$= \frac{760}{t+10}$ Storm duration (t) = 5-20 min

or $= \frac{1020}{t+20}$ ∴ t = 20-100 min.

A = Area of catchment in hectares. (1 ha = 10^4 m^2).

∴ Total quantity of sewage (Q) = $Q_{sanitary} + Q_{storm\ water}$

→ Good accuracy couldn't be achieved.

→ Doesn't consider shape, slope & ditches of rainage area.

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Sanitation System

A Sanitation system includes the collection, storage, transport, treatment & disposal of refuse.

① Conservancy System

→ Tradition system in which garbage is collected separately in dustbi & conveyed by truck or tractor.

→ The combustible & non-combustible are sorted out.

→ The combustible is burnt & non-combustible & inorganic are buried. (जमीन)

→ Feces (मल) & urine of human was collecting in bucket & truck for disposal outside.

→ Directly involvement of human so risk to the helth.

② Water Carriage System

→ It is modern method in which water is used as medium to carry waste to the point of final disposal.

→ The quantity of water is high (99.9 %) that wastes become liquid which is carried by sewer.

→ The waste coming from toilet carriage water & also sullage is led to the sewer.

→ Storm water may be disposed separately or combined with sanitary sewage.

Source of sanitary sewage

① Domestic Sewage → sewage derived from residential building, individual houses, from commercial, institutional & similar building such as offices, school, Cinemas & hotels etc.

② Industrial sewage → sewage obtained from manufacturing plants of industries.

③ Ground water infiltration → Ground water infiltration into sewer through the pipe joints & entry. 2 to 5 % of DWF shall be considered

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as for the infiltration in sewer network.

④ Illegal or unauthorized Connection → It includes entry of rain water & unauthorized connection made by the people in the sewer.

⑤ Private sources → It include waste water generated from private sources like tube well, well etc.

Maximum Velocity	
Earthen Sewer	0.6 – 1.2
Brick sewer	1.5 – 2.5
Concrete sewer	2.5 – 3.5
Stonewere Sewer	3 – 4.5
C.I sewer	3.5 – 4.5
Galazed brick sewer	5
Types of sewer	Max^m Velocity (m/sec)

Minimum Velocity

for separate system = 0.6 m/s

for Combined system = 0.75 m/s

Self-cleaning Velocity

→ The minimum velocity at which solid particle will remain in suspension without settling in the invert of sewer.

Dia^m of sewer	self-cleaning velocity
< 25 cm	1
25 – 60 cm	0.75
> 60 cm	0.60

Design of Sewer

Criteria

ⓐ Sewage → 99.9 % liquid
→ 0.1 % Solid

ⓑ Specific gravity > 1

ⓒ Design period = 25 – 30 year.

ⓓ Velocity of flow * Max^m or limiting or non-scouring velocity.

→ The max^m velocity in the sewer line at which no scouring action or abrasion takes place.

ⓔ Diameter of pipe : minimum diameter = 15 cm

Maximum diameter = 300 cm

Recommended diameter = 20 cm

In hilly area, minimum diameter = 10 cm.

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⑥ sewer gradient — Minimum gradient = 1:100

Maximum gradient = 1:20

Diam of sewer	Gradient
10cm	1:60
15cm	1:100
22.5cm	1:150

Components of sewer

① Sewer pipe → Circular

② Manhole → Used for inspection, cleaning, repair & maintenance etc.

→ provided at every change in alignment, gradient, junction etc.

→ Diameter of manhole = 50 cm.

→ Distance betⁿ two manhole = 50 – 150m.

Types	① Shallow manhole	② Intermediate manhole	③ Deep manhole
Depth	0.7 – 0.9m	0.9 – 1.5m	> 1.5m

③ Drop manhole → Level difference betⁿ branch sewer & main sewer is 60cm, then drop manhole is provided. → Inspection arm is provided.

④ Lamp manhole → Small opening provided on sewer to permit the insertion of lamp.

⑤ Inverted Syphon (Depressed sewer) → When the road, canal etc, cross the sewer line, the sewer placed below road, canal etc.

→ HGL is above the flow pipe. → Used of no. of pipe = 3

⑥ Catch pit → Small masonry chamber (75 to 90 cm in diam as well as depth. → Constructed below the street.

→ Prevent of debris, silt, sand to sewer.

⑦ Letache → infiltration of waste water into soil.

⑧ Inlet → Small box like chamber made of brickwork or concrete, having an opening at the top in vertical or horizontal direction for the entry of storm water & surface wash.

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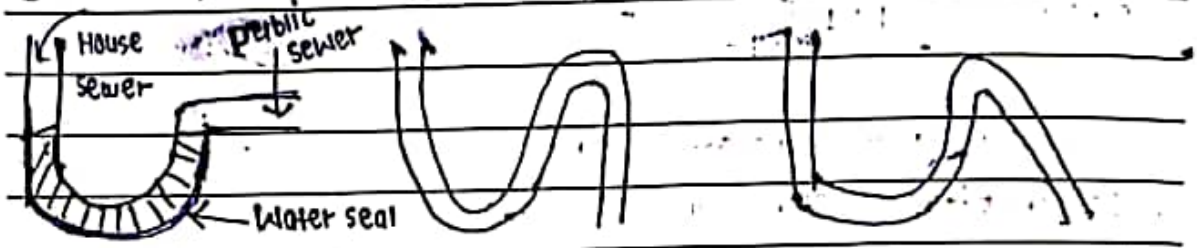
⑨ Traps

Intercepting traps → Trap are the fitting required to prevent the entry of foul gas & drain gas into house.

Types

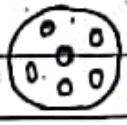
Ⓐ P-Trap Ⓑ S-Trap ©) g- Trap



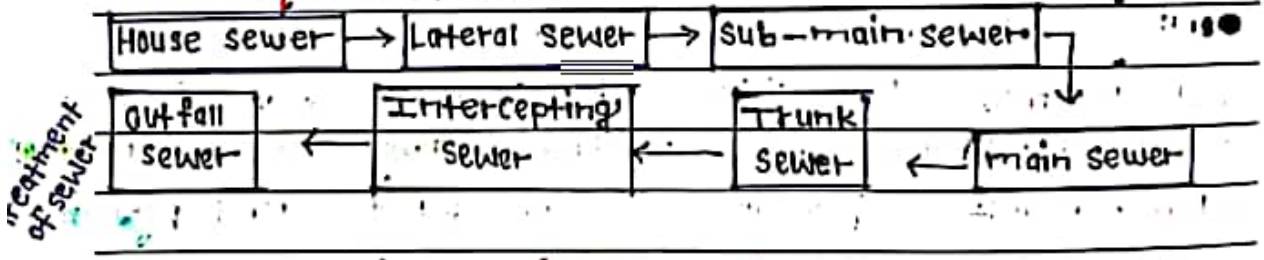
→ perpendicular leg → Parallel leg → Oblique leg.

Nahni Trap → made up of cast iron.

→ Used in bathroom, kitchen, toilet etc.



Sequence of sewer



Excreta Disposal & Unsewered area

→ for the disposal of human waste urine & feces without water Carrage system various type of latrine may be operated.

→ latrine are commonly used for disposal of human excreta in unsewered area.

Types of Latrine

① pit Latrine/privy

② VIP Latrine (Ventilated Improve pit)

③ pour flush Latrine.

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Pit Lattrine

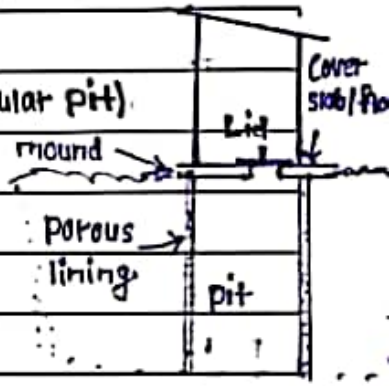
→ It is widely used in least developed or developing country.

→ Manually dug or bored vertically hole, which accumulation for human excreta. → Suitable in rural area.

→ 1m x 1m (Squire pit) → 90 – 120 cm (Circular pit)

→ Depth = 1–2m

→ minimum horizontal distance from a hand pump = 30m.



Septic Tank

→ Used in unsewered area. → Improve method of excreta disposal.

→ Septic tank is combination of sedimentation & digestion tank in which suspended solid settle down at the bottom of the tank.

→ Anaerobic digestion of liquid & sludge. (अक्सिजन चाहिदैन)

→ Rectangular watertight chamber constructed of brickwork or stonework or RCC etc.

Design of Septic Tank

Numerical Important

ⓐ Detention time (t) = 1–3 days, generally 24 hour

ⓑ Width (B) = 0.75 – 4m (B_{min} = 0.75 m)

ⓒ Depth (d) = 1 – 1.8 m

ⓓ L/B ratio = 2–4

ⓔ Free board = 0.3 – 0.5 m

ⓕ Total effective volume is compacted as following.

→ Volm of sedimentation/settling of sewage (V_1) = $q \times t$ (m^3)

→ Volm of sludge digestion (V_2) = $0.04 \cdot 25 \times N$ (m^3)

→ Volm of storage of sludge (V_3) = $Cds \times N$ (m^3)

Where; Cds = Sludge digestion rate, which depend on cleaning period.

for 3 years, Cds = 0.085

N = Number of user

∴ Total Volume (V) = $V_1 + V_2 + V_3$

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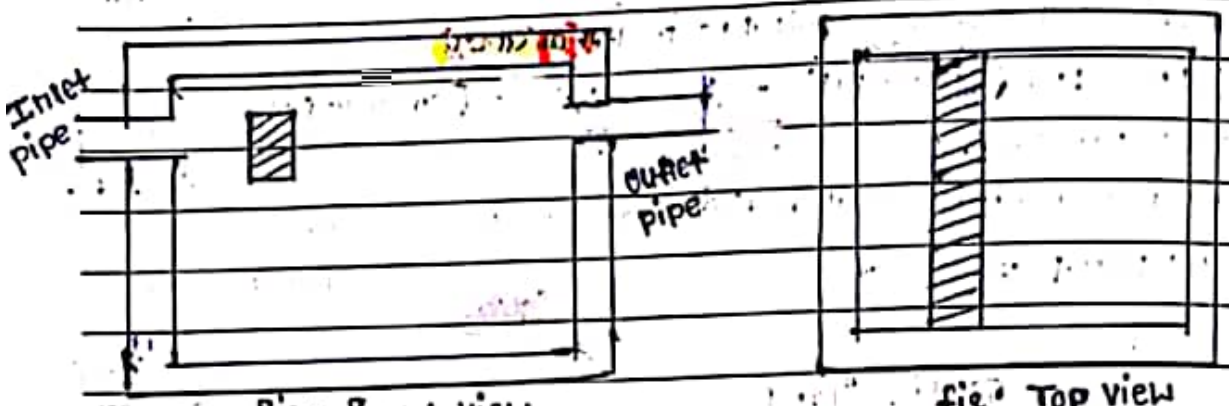
Cleaning period	6 month	1yr	2yr	3yr
Sludge digestion rate	0.0283	0.049	0.0708	0.085



fig; front view

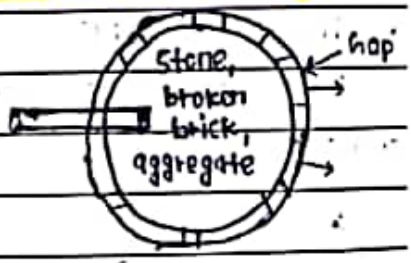
fig; Top view

Soak pit

→ It is circular with allow effluent from Septic tank to percolate into soil.

→ Consist of pit (lined / unlined).

→ pit filled with brick, stone, aggregate.



Design Criteria

① Diameter = 0.9 – 3.5 m

② Effective depth (d) = 1m

③ Max^m rate of effluent (I) = $\frac{130}{\sqrt{t}}$

Where, t = standard percolation rate (min/cm).

④ Ground water table should be 2m from bottom of soak pit.

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Stand post → No. of people = 100 per stand post

→ Horizontal Walking distance = 150m (exceptional - 250m)

→ Vertical Walking distance = 50 m (exceptional — 80m)

Note : First piped water supply system ⇒ Bir dhara system.

→ (1891 - 1893) → Location : Kathamandu

→ Rana prime minister Bir sumsher.

Melamchi Water Supply System

Name of Sources : Melamchi, Yangri & Larka River

Total designed capacity : 510 MLD (170x3)

No. of phases : 3

Start of first phase : 1998

Completion of first phase : 2021 (2077/78)

" " Whole project : 2025 (2081/82)

Length of tunnel : 26.50km

Access road : 43 KM

Donor (main) : ADB