

CHAPTER THREE

3. SOURCES OF WATER

3.1 Raw Water Quality and Source Selection

The type treatment depends on the quality of the water source. In general, the quality of raw water should be good enough to provide finished water quality with a minimum number of treatment processes and at the least treatment cost. It is, therefore, essential that careful consideration and extensive engineering evaluations, including a water resource development investigation, be conducted as part of source selection. Availability of water from the source should at least be equal to the demand. Factors such as quantity, quality, reliability, safety of source, water rights, and environmental impacts, along with capital and operational costs of the project, enter into the decision making.

Types of water sources fall into two general categories:

- (i) surface water sources such as rivers, lakes, and impoundments on rivers and streams, and
- (ii) Groundwater sources, principally wells and spring. Ultimately depends upon rainfall, which is a natural feature.

Accordingly, any source of water is selected for the purpose of water supply scheme after considering the following points:

1. *Quality of water of the source,*
2. *Quantity of the yield, and*
3. *Location of the source*

➤ **The quality of water is determined by physical, chemical and biological tests.** On the basis of these tests, results sources of water can be divided into four different classes.

Class I: source of this standard is the best available and does not require any other treatment except disinfection. This is also known as highly satisfactory source of water and many deep wells water comes under this category.

Class II: this is categorised as satisfactory standard and will require treatment like filtration and disinfection only. Water from shallow wells, springs and lakes may come in this category.

Class III: this is also classifies as specious (baseless) water source. This water requires treatment like coagulation, filtration, and sometimes special auxiliary treatment like aeration, softening and followed by filtration.

Class IV: this is the unsatisfactory type of water source. This water may contain toxic substances or highly polluted with sewage and industrial wastes. This cannot be purified by the normal treatment used for water supply and never taken up as a water supply source.

- The quantity of water available from a source is its yield, which can be measured by various methods depending upon the nature of the source i.e. ground water or surface water source and upon the information available. The yield of groundwater can be determined by direct pumping (pump test result), whereas for measuring of surface water various methods were adopted.
- A source preferably should be in close vicinity of the town. Out of two nearby sources, the one having better should be away from the point of waste disposal, and in case of river it should be well off in the upstream side.

3.2 Factors Governing the Selection of Source of Water

The following important factors are generally considered in selection of a particular source for supplying water to a city or a town.

- (i) **The Quantity of Available Water:** the quality of water available at the source must be sufficient to meet the various demands during the entire design period of the scheme. If sufficient quantity of water is not available in the vicinity of the area, we may have to think of bringing water from distant sources.
- (ii) **The Quality of Available Water:** the water available at the source must not be toxic, poisonous or in any other way injurious to health. The impurities present in the water should be as less as possible, should be removed easily and economically by normal treatment methods.

- (iii) **Distance of the Source of Supply:** the source of water must be situated as near the city as possible. Because when the distance b/n the source and the city is less, lesser length of pipe conduits and other associated appurtenances are required less, thereby reducing the cost.
- (iv) **General Topography of the Intervening Area:** the area or land b/n the source and the city should not be highly uneven i.e. it should not contain deep valleys or high mountains and ridges. In such uneven topographies the cost of supports and joints for carrying water pipes in valleys and that of constructing tunnels in mountains shall be enormous.
- (v) **Elevation of the Source of Supply:** the source of water must be on a high contour, lying sufficiently higher than the city or town to be supplied with water, so as to make the gravity flow possible. When the water is available at lower levels than the average city level, pumping has to be resorted to, which involves huge operational cost and frequent possible breakdowns.

3.3 Ground Water Sources and their Occurrences

It is rainfall which is the main source of ground water. The rainfall that percolates below the ground surface passes through the voids of the rocks and joins the water table. This precipitation filters into the ground or seeps through cracks or solution passages into the rock formations, and penetrates deep enough to reach the ground water table. The water table is the upper limit of the zone of saturation. These voids are generally interconnected, permitting the movement of the ground water. Evidently the mode of occurrence of groundwater depends largely upon the type of formation, and the geology of the area. The volume of water contained in the ground water reservoir in any localized area i.e. the water storage capacity of the ground water is dependent upon

- (i) *the porosity and permeability of the rocks,*
- (ii) *the rate at which water is added to it by infiltration, and*
- (iii) *the rate at which water is lost from it by evaporation, transpiration, seepage to surface courses, and withdrawal by man.*

The most common methods used in groundwater exploration are:

- *Study of any available geological maps and reports*
- *Study of topographical maps (e.g. 1: 50,000 scale)*
- *Examination of any existing wells*
- *Hydrogeological survey*

- *Surface geophysical investigations (including electrical resistivity, seismic refraction, well logging)*
- *Aerial photography and satellite imagery*
- *Airborne geophysical methods (including magnetic, radiometric and electro-magnetic measurements)*
- *Test wells (drilling, pumping tests, geophysical logging, radioactivity logging, (radio isotopic) tracer investigations, and chemical water testing (electric conductivity))*

Ground water must generally be raised from aquifers by pumping in the form of wells. Some of the common different types of wells depending on the requirement, nature of geological formations, methods of construction, etc., are:

- (a) Dug wells: also known as open wells. These are shallow wells constructed by open excavation, and should be sunk 7.5m below ground water table. Normally water is lifted manually from a dug well, but if the yield is of ample, pumping may be necessary to install.

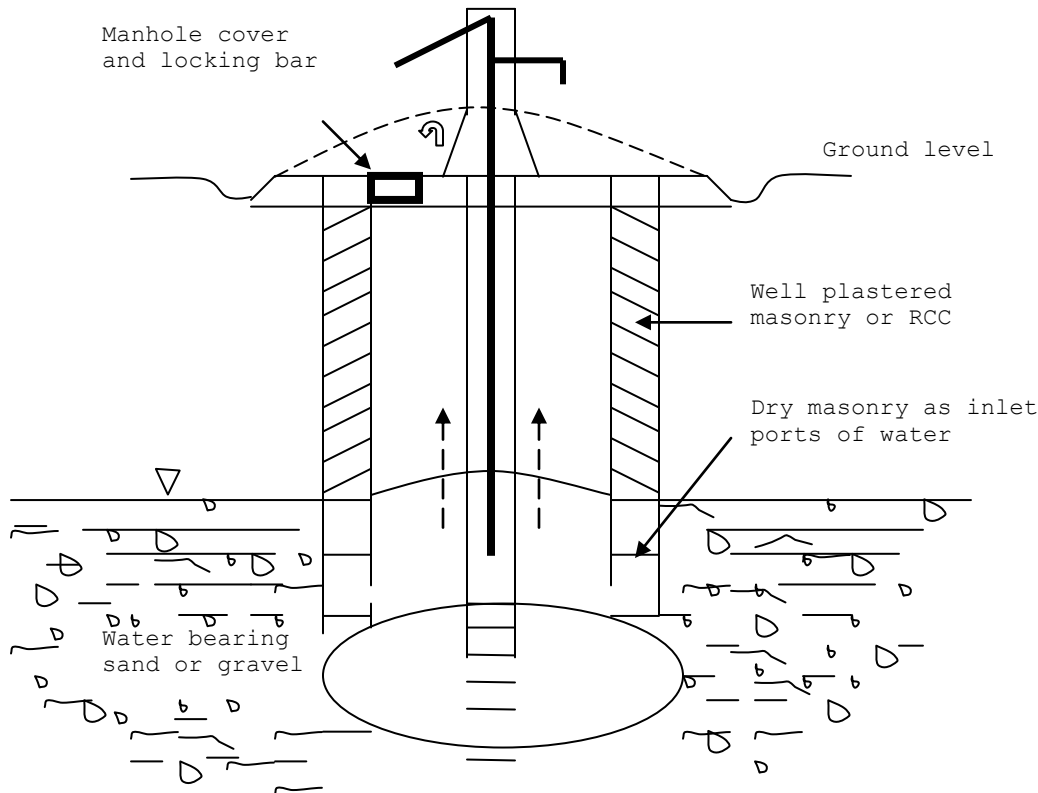
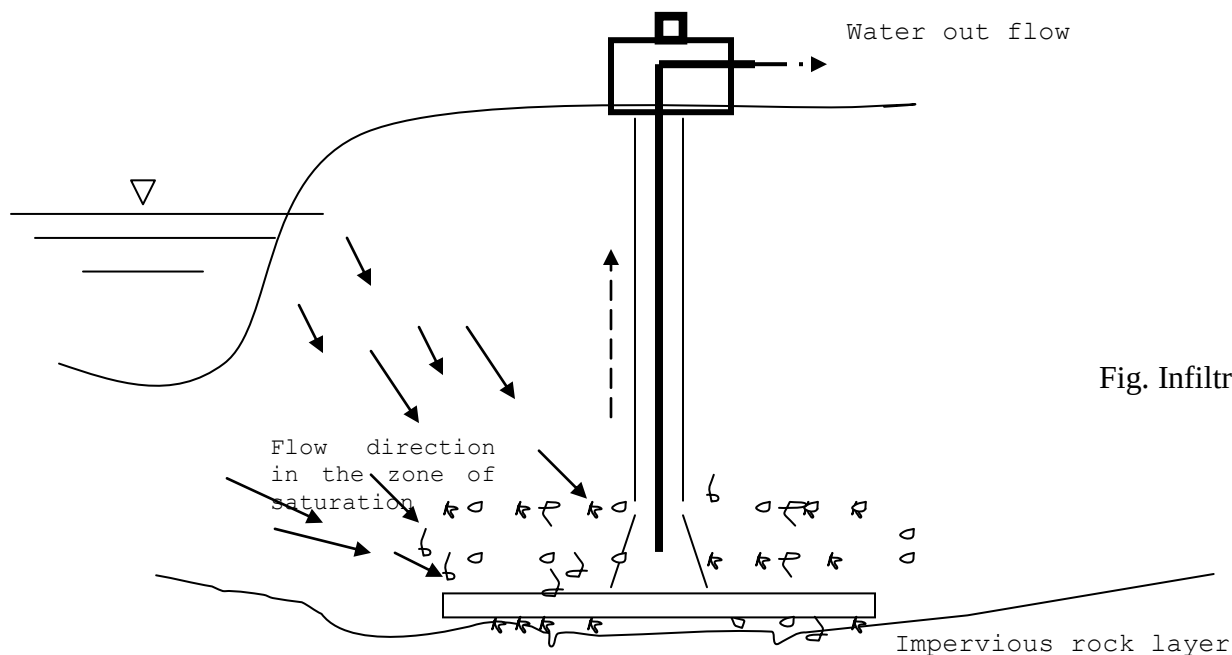


Fig. Dug well

- (b) Infiltration well: in the banks of rivers, particularly sandy alluvial deposits, well is sunk for tapping underground water on a large scale. The wells are connected by pipe lines to convey the pumped water for further distribution.



- (c) Bored/drilled well: in soils that are sufficiently stiff and cohesive to prevent the serious caving, the wells are drilled by mechanical means (auger). These augers are useful for wells up to 15 cm in diameter and depths 30 to 100 meters or more.

3.3.1 Ground Water Yield Estimation Methods

The yield of a well depends upon the water storage capacity of the aquifer, its hydraulic characteristics like permeability, porosity and transmissibility. The condition in which water is extracted through penetration of pervious layer could be termed as unconfined aquifer, if on the other hand the water is extracted from an aquifer located between two impervious layers is known as confined aquifer. Theoretically, the velocity of the ground water approaching the well can be determined by the Darcy's equation.

$V = KS$ where; V = face velocity of water entering into well

K = coeff. of permeability, dimen. of velocity

S = slope of the hydraulic gradient

The coefficient of permeability, k , cm/sec at temperature of 10°C

Flow type	Nature of soil
k -value	
Good aquifer $10^{-3} - 10^2$	Clean gravel, sand or mixture
Poor aquifer $10^{-7} - 10^{-3}$	Fine sand, silt, mixture of sand, silt & clay
Impervious $10^{-9} - 10^{-7}$	un-weathered clays

Then the discharge can be estimated as; $Q = AV = AKS$

Coefficient of permeability is the rate of flow of water from an aquifer through a unit cross sectional area, under a unit hydraulic gradient and at a temperature of 10°C .

Coefficient of transmissibility is the rate of flow of water through a vertical strip of water bearing stratum/aquifer through per unit width and full depth under a unit hydraulic gradient at a standard temperature of 10°C , which is dimensionless.

The coefficient of permeability, K , and coefficient of transmissibility, T , can be correlated by;

$$T = Kd \quad \text{where; } d = \text{depth of aquifer}$$

Unconfined aquifer: the top most upper water bearing stratum having no confined impermeable over burden lying on it. This aquifer when the water is pumped at constant rate a cone of depression will form and draw down will be steady. The line of contact of the cone of depression with the static water table is known as “circle of influence”.

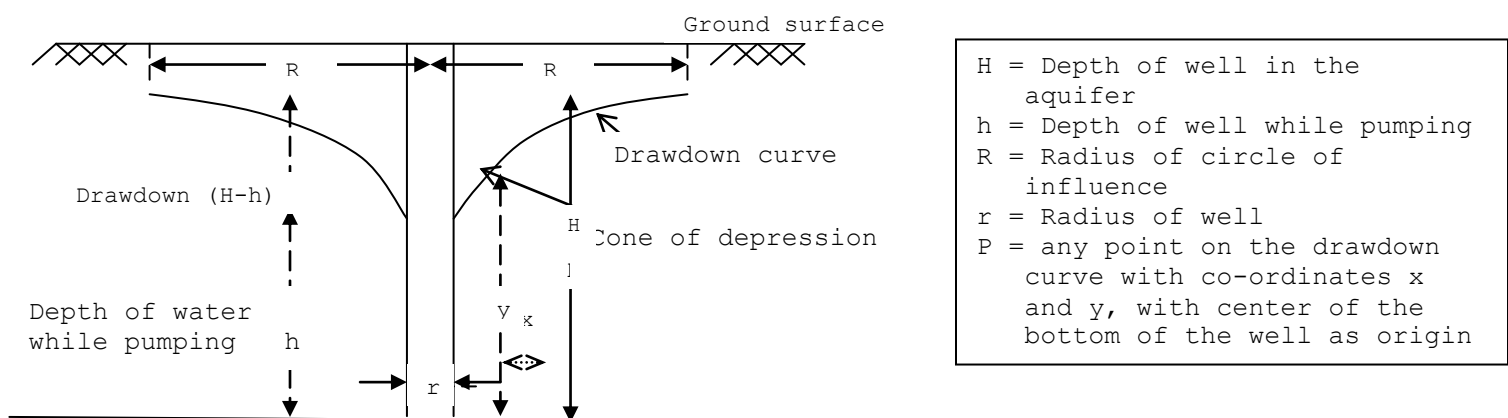


Fig. Unconfined aquifer

Velocity, $V = KS$; and the yield, $Q = AKS$; where S = slope of draw down curve
 $= dy/dx$ and $A = 2\pi xy$

$$Q = (2\pi xy)K \cdot dy/dx \Rightarrow Q \cdot dx/x = 2\pi Ky \cdot dy$$

Integrating both sides and solving,

$$Q = \pi K \frac{H^2 - Y^2}{\log_e \frac{R}{x}}, \text{ but } x = r \text{ at } y = h$$

$$Q = \pi K \frac{H^2 - h^2}{\log_e \frac{R}{r}} \Rightarrow Q = 1.36K \frac{H^2 - h^2}{\log_{10} \frac{R}{r}}$$

Confined aquifer- this is the condition of flow from an artesian well i.e. when an aquifer is confined on its upper and under surface by impervious rock formations.

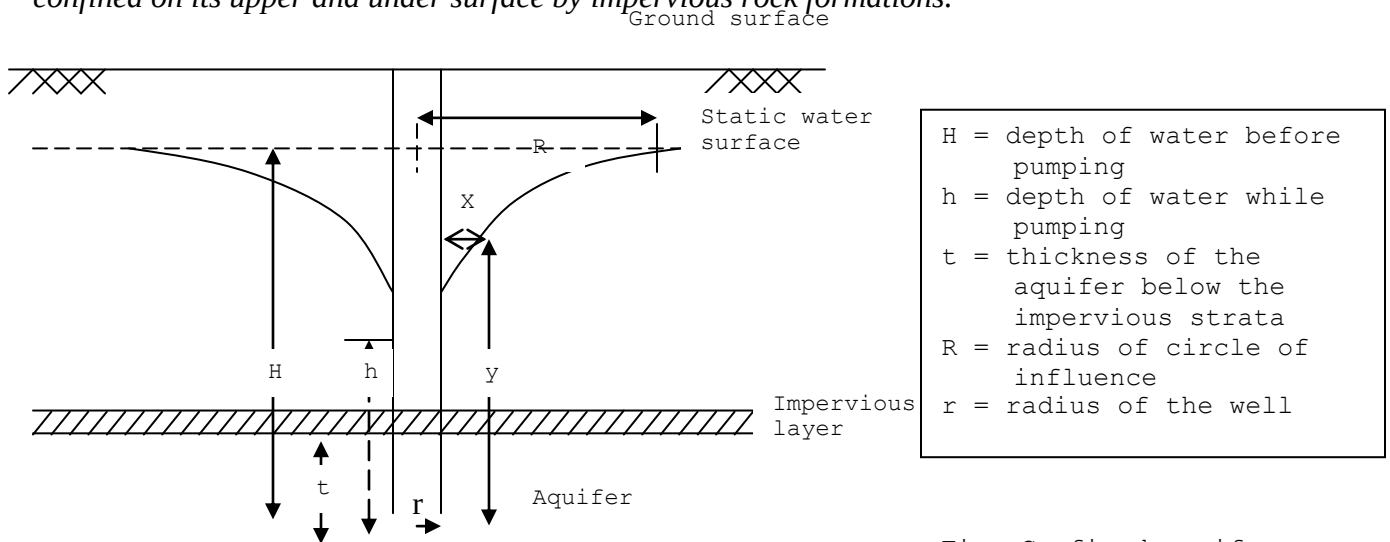


Fig. Confined aquifer

$$Q = AV = AKS = (2\pi t) \cdot x \cdot K \cdot dy/dx \Rightarrow Q \cdot dx/x = 2\pi t K dy$$

Integrating both sides and solving,

$$Q = 2\pi t K \frac{(H - h)}{\log_e \frac{R}{r}} = 2.73Kt \frac{(H - h)}{\log_{10} \frac{R}{r}}$$

Example:

A pumping test was carried out on a 15 cm diameter well and the following observations were made:

- (i) Rate of pumping 230l/s
- (ii) Depth of water in the well before pumping is 45 m.
- (iii) The drawdown observed in the neighbouring wells during pumping:
 - 1.5 m in a well at a distance of 30 cm

- 0.5 m in a well at a distance of 60 cm

Find out (i) the radius of circle of influence

(ii) the coefficient of permeability

Solution: Since the pumping lowers the water levels in the neighbouring wells, they are inside the circle of influence, and they will have the same drawdown curve.

$$Q = 1.36K \frac{H^2 - h^2}{\log_{10} \frac{R}{r}} \quad H = 45\text{m}, h_1 = 45 - 1.5 = 43.5\text{m}, h_2 = 44.5\text{m}, r = 0.075\text{m},$$

$$r_1 = 30, r_2 = 60$$

$$Q = 1.36K \frac{45^2 - 43.5^2}{\log_{10} \frac{R}{30}}, \text{ Again, } Q = 1.36K \frac{45^2 - 44.5^2}{\log_{10} \frac{R}{60}}$$

Solving by trial and error, $R = 96\text{m}$; $Q = 230\text{l/sec} = 0.23 \text{ m}^3/\text{sec}$

$$0.23 = 1.36K \frac{45^2 - 43.5^2}{\log_{10} \frac{96}{30}}$$

$\Rightarrow$ The coefficient of permeability, $K = 5.0 \times 10^{-4} \text{ m/sec}$ or $5.0 \times 10^{-2} \text{ cm/sec}$

Example:

Find out the discharge of the tube well mentioned above if the depression head be 7.5m.

Solution; $Q = ?$

From the above example: $R = 96\text{m}$, $K = 5.0 \times 10^{-4} \text{ m/sec}$, $r = 0.075\text{m}$

$$Q = 1.36K \frac{H^2 - h^2}{\log_{10} \frac{R}{r}} = 1.36 * 5.0 * 10^{-4} \frac{45^2 - 37.5^2}{\log_{10} \frac{96}{0.075}} = 2.0 \text{ m}^3/\text{sec}$$

Example:

A 30 cm, gravity well is being pumped at the rate of 1350lpm. Measurements are made in nearby test wells at the same time are as follows;

(i) drawdown at 6m away = 4.5m

(ii) drawdown at 30m away = 0.9m

(iii) distance of the groundwater table above bottom of the well = 75m

Determine; the drawdown in the well

Solution: $Q = 1350\text{lpm} = 1350 * 60 / 1000 = 0.0225 \text{ m}^3/\text{sec}$

$$0.0225 = K \frac{75^2 - 70.5^2}{\log_{10} \frac{R}{6}} = K \frac{75^2 - 70.5^2}{\log_{10} \frac{R}{6}} \quad (1)$$

$$\text{Again, } 0.0225 = K \frac{75^2 - 74.1^2}{\log_{10} \frac{R}{30}} \quad (2)$$

By solving (1) and (2), we get $R = 46\text{m}$ and $K = 0.00003$

$$\text{Now, } 0.0225 = 0.00003 * \frac{75^2 - h^2}{\log_{10} \frac{46}{0.15}} \Rightarrow h = 62\text{m}$$

$$\text{Drawdown } 75-62 = 13\text{m}$$

Example:

Calculate the discharge of a tube well of diameter 80cm in cubic meter per day. The thickness of water bearing strata and drawdown are 10m and 4m respectively. Assume the radius circle of influence as 30m and permeability constant as $20 \text{ m}^3/\text{day}/\text{unit area}$.

$$\text{Solution: } Q = 1.36K \frac{H^2 - h^2}{\log_{10} \frac{R}{r}} \Rightarrow Q = 1.36 * 20 \frac{100 - 36}{\log_{10} \frac{30}{0.4}} = 928 \text{ m}^3 / \text{day}$$

Example:

A fully penetrating well of diameter 0.4 is abstracting water from 2.5m thick confined aquifer. The steady state draw downs at 8m and 50m were observed to be 2.5m and 0.6m respectively. Compute the steady state discharge from the well. The coefficient of permeability is 10^{-3} m/s

$$\text{Solution: } Q = 2.73Kt \frac{(H - h)}{\log_{10} \frac{R}{r}}$$

$$Q = 2.73Kt \frac{2.5}{\log_{10} \frac{R}{8}} = 2.73Kt \frac{0.6}{\log_{10} \frac{R}{50}} ; \text{ Solving } R = 90\text{m}$$

$$Q = 2.73 * 10^{-3} * 2.5 * \frac{2.5}{\log_{10} \frac{90}{8}} = 0.0162 \text{ m}^3 / \text{sec}$$

$$\text{Again, } 0.0162 = 2.73 * 10^{-3} * 2.5 * \frac{50 - h}{\log_{10} \frac{90}{0.2}}$$

$$\text{Or, Drawdown in the well } = (H-h) = 6.29\text{m}$$

Spring Water

Springs are found mainly in mountainous or hilly terrain. A spring may be defined as a place where a natural outflow of groundwater occurs.

Spring water is usually fed from a sand or gravel water-bearing soil formation called an aquifer, or a water flow through fissured rock. Where solid or clay layers block the underground flow of water, it is forced upwards to the surface. The water may emerge either in the open as a spring, or invisibly as an outflow into a river, stream, lake or the sea. Where the water emerges in the form of a spring, it can easily be tapped.

Identification of spring source

Local people, especially women (as drawers of water), but also farmers, hunters and grazers, have a good knowledge of the location of springs and their characteristics. These people are the primary sources of information in the identification process. In the dry season, green vegetation in a dry area may also be an indication of a spring source.

Types of spring sources

Springs are classified according to the conditions under which water flows to them. Some surface under pressure, while others do so as a result of discontinuities in the strata that held the water underground. To understand the possibilities of water tapping from springs, the distinction between gravity springs and artesian springs is most important.

Gravity depression springs

Gravity springs occur in unconfined aquifers. Where the ground surface dips below the water table, any such depression will be filled with water. Gravity depression springs usually have a small yield and a further reduction occurs when dry season conditions or nearby groundwater withdrawals result in the lowering of the groundwater table.

Gravity overflow springs

A larger and less variable yield from gravity springs is obtained where an outcrop of impervious soil, such as a solid or clay fault zone, prevents the downward flow of the groundwater and forces it up to the surface. At such an overflow spring, all the water from the recharge area is discharged. The flow will be much more regular than the recharge by rainfall. Even so, an appreciable fluctuation of the discharge may occur and in periods of drought some springs may cease to flow completely.

Artesian depression spring

Artesian groundwater is prevented from rising to its free water table level by the presence of an overlying impervious layer. That is the reason why artesian groundwater is under pressure. Artesian springs are the sites where the groundwater comes to the surface.

Artesian depression springs are similar in appearance to gravity depression springs. However, the water is forced out under pressure so that the discharge is higher and there is less fluctuation. A drop of the artesian water table during dry periods has little influence on the artesian groundwater flow.

Artesian fissure spring

Artesian fissure springs form an important variant of this type of spring. Again the water emerges under pressure, this time through a fissure in the impervious overburden. Fissure springs exist in many countries and are widely used for community water supplies.

Artesian overflow spring

Artesian overflow springs often have a large recharge area, sometimes a great distance away. The water is forced out under pressure; the discharge is often considerable and shows little or no seasonal fluctuation. These springs are very well suited for community water supply purposes. Artesian springs have the advantage that the impervious cover protects the water in the aquifer against contamination. The water from these springs is usually bacteriologically safe.

Spring water quality

In general, spring water is of good quality. Pathogenic contamination is unlikely if the source meets certain criteria.

The soil formation should be thick enough for natural filtration and biological action to remove pathogenic organisms before the water enters the aquifer feeding the spring. The type of soil determines the speed of the flow through the voids in the soil and so influences the purification mechanisms and the concentration of suspended solids. One of the key signs of a good spring is that the water maintains a constant temperature throughout the day. This temperature is just below the average air temperature. The water should also be colourless. Variation of water temperature during the day and colouration of water shortly after rains are indications of a poor quality spring source. It may have its water-bearing soil layer not deep enough or rapid infiltration of surface water through the topsoil

The spring water quantity

The quantity of water a spring produces is known as its yield. Information about the yield is crucial in the decision-making process for the tapping of a spring. Yield is studied in terms of flow rate and consistency. Variation in the yield of a spring during the dry season and the rainy season is an important criterion to determine whether the spring is a suitable source. If the ratio between the highest yield in the rainy season and the yield in the dry season is below 20, then the spring has an acceptable consistency and can be regarded as a reliable source in both wet and dry seasons. Take into account that the highest and the lowest yield do not occur at the beginning of the rainy season and at the end of the dry season but typically a couple of weeks (or even months) later, depending on the soil characteristics.

The yield is highly influenced by the water storage capacity of the aquifer. When the water velocity in the saturated stratum gets too high, the pores through which the water passes tend to become choked so that the flow becomes considerably reduced. Limestone and volcanic rock areas do not experience this effect.

Estimating spring yield

A spring yield is measured in litres per second (l/s). The measurement process involves two selected trained villagers who measure the discharge from the spring over the study period. The process starts with the construction of an earth dam. Spring water retained by the dam is drained through a pipe. One villager collects the water with a container of a known volume while the other measures the time needed to fill the container. The pipe diameter and container size are chosen such that the water outflow will not fill the measuring container in less than five seconds. Sometimes several pipes are used. Four readings are taken during the day and day averages are

calculated, expressing the discharge in l/s. This is repeated once every week for the measuring period. In this way, the minimum and maximum yields are determined

3.4 Surface Water Sources

Surface sources are those sources of water in which the water flows over the surface of the earth and it is thus directly available for water supplies. The important of these sources are:

- (i) ponds and lakes*
- (ii) streams and rivers*
- (iii) impounding reservoirs*

Actually, rainfall is the primary source of all water. However, the rainfall is not constant at all places and its variation depends upon the altitude of the place, nearness to the sea and hills, etc.

The development of surface water supplies depends upon the nature of their sources and involves:

- (i) the selection, preparation and control of catchment area*
- (ii) the choice and treatment of reservoirs sites as well as operation of reservoirs and*
- (iii) the design, construction and maintenance of dams and dikes and*
- (iv) Intake and outlet structures.*

Whenever practicable a river intake should be sited

- Where there is adequate flow;*
- At a level that allows gravity supply to minimise pumping costs;*
- Upstream of densely populated and farming areas to reduce silt inflow;*
- Upstream of cattle watering places, washing places and sewer outlets
(to eliminate pollution of the water);*
- Upstream of bridges (to reduce velocity/turbulence).*

Intake designs aim to avoid clogging and scouring and to ensure the stability of the structure even under flood conditions. Where the river transports no boulders or rolling stones, an unprotected intake may be adequate

The engineering problems encountered lie within the purview of hydrology, hydraulics, soil mechanics, structural mechanics and sanitation. It is important to know the yield of water of a surface source prior to selecting it as a source of water supply. Different formulae used for

knowing the yield of a catchment are useful for a particular region where it has been established and obtained on annual basis. For large stream with high discharge the method applicable is measuring discharge by area velocity method, mathematically expressed as: $Q = A.V$

Impounded reservoirs also known as storage reservoirs are formed by obstructing the passage of water while constructing a dam or dike across a flowing stream. This can store water during high rate of flow and will supply it during periods of high rates of demand.

The quality of water taken from a surface source depends upon the character and the area of water shed, its geology and topography, the extent and nature of the development by man, time of year and weather conditions. The quality of water from streams is generally more variable and less satisfactory than that from ponds and lakes. Water from lime stone regions is harder but less corrosive than water from granite regions. Surface sources in heavily polluted areas are affected by sewage and industrial wastes. From sanitary stand point, pollution by man as a result of his pursuits is the most significant. The net result of man made and natural pollution is to produce colour, turbidity, tastes and odours, hardness bacteria, and other micro-organisms in water supply. It is a function of water treatment to correct such impairment before surface water is used for domestic or industrial supplies.