# SRI SIDDHARTHA ACADEMY OF HIGHER EDUCATION

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**AGALKOTE, TUMAKURU – 572107,**
**Karnataka**

**Project Report**
**On**

# "Study of Seawater Intrusion Using Isotope Analysis along Karnataka Coast"

Submitted in partial fulfillment of requirements for the award of degree of

**BACHELOR OF ENGINEERING**
**IN**
**CIVIL ENGINEERING**

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# ABSTRACT

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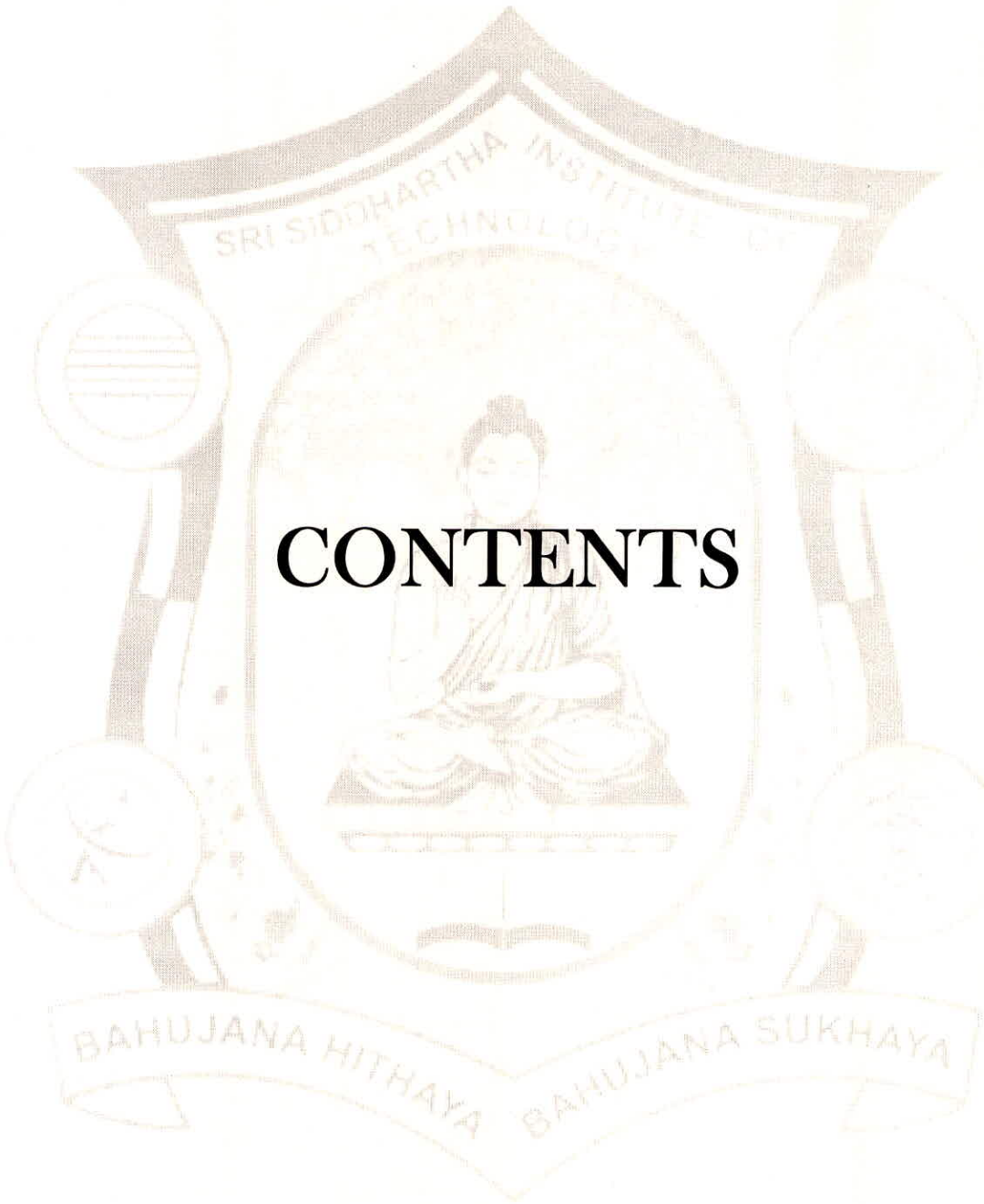
Sea water intrusion is one of the important threats to water availability in the coastal zones. A study has already been done on the coast of Bengal, Orissa, and Andhra Pradesh.

Surveys were conducted along the coast of Karnataka which included the 3 districts of Dakshina kannada, Udupi and parts of Uttara kannada, According to the complaint received it could be inferred that sea water intrusion is indeed a problem in Karnataka coast. The study is of vital importance as the population density along the coast is very high.

Isotopes techniques are of at most importance in Karnataka as the water exists in the fractures of rocks (hard rock region). Isotopes study was extended to the coastal region as it was felt that this methodology would be able to identify the sea water as source of pollution and nothing else.

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# INTRODUCTION

# CHAPTER-1

# INTRODUCTION

## 1.1 Groundwater:

Groundwater is commonly understood to mean water occupying all the voids within a geologic stratum (Todd, 3rd edition). Thus, groundwater is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells.

We know oceans contain about 97% of the liquid water present in the Earth, rest 3% is freshwater present inland. Groundwater makes up about 1% of the water on the Earth. It makes up to 35 times the amount of water in lakes and streams. Groundwater occurs everywhere beneath the Earth's surface, but is usually restricted to depth less than about 750 meters. The volume of groundwater is equivalent to a 55-meter thick layer spread out over the entire surface of the Earth.

**Origin of Groundwater:**

The origin of groundwater is primarily one of the following:

Groundwater derivedfrom rainfall andinfiltration within thenormal hydrological cycle. This kind of water is called meteoric water. The name implies recent contact with the atmosphere.

Groundwater encountered at great depths in sedimentary rocks as a result of water having been trapped in marine sediments at the time of their deposition. This type of groundwater is referred to as connate waters. These waters arenormally saline.It is accepted that connatewater isderived mainly or entirely from entrappedsea water as original sea water has moved from its original place. Some trapped water may be blackish.

Fossil water if fresh may be originated from the fact of climate change phenomenon, i.e., some areas used to have wet weather and the aquifers of that area were recharged and then the weather of that area becomes dry.

**Groundwater and Hydrological Cycle:**

The hydrological cycle is the most fundamental principle of groundwater hydrology. Water evaporates and travels into the air and becomespart of a cloud. It falls down to earth as precipitation. Then it evaporates again. This happens repeatedly in a never-ending cycle. This hydrologicalcycle never stops. Water keeps moving and changing from a solid to a liquid to a gas, repeatedly. Precipitation creates runoffthat travels over the ground surface and helps to fill lakes and rivers. It also percolates or moves downward through openings in the soiland rock toreplenish aquifers under the ground. Some places receive more precipitation than others do with an overview balance. These areas are usually close tooceans or large bodies of water that allow more water to evaporate and form clouds. Other areas receive less. Often these areas are far from seawater ornear mountains. As clouds move up and over mountains, the water vapour condenses to form precipitation and freezes. Snow falls on the peaks. The following figure (fig.1.1.1) describes and represents hydrological cycle.

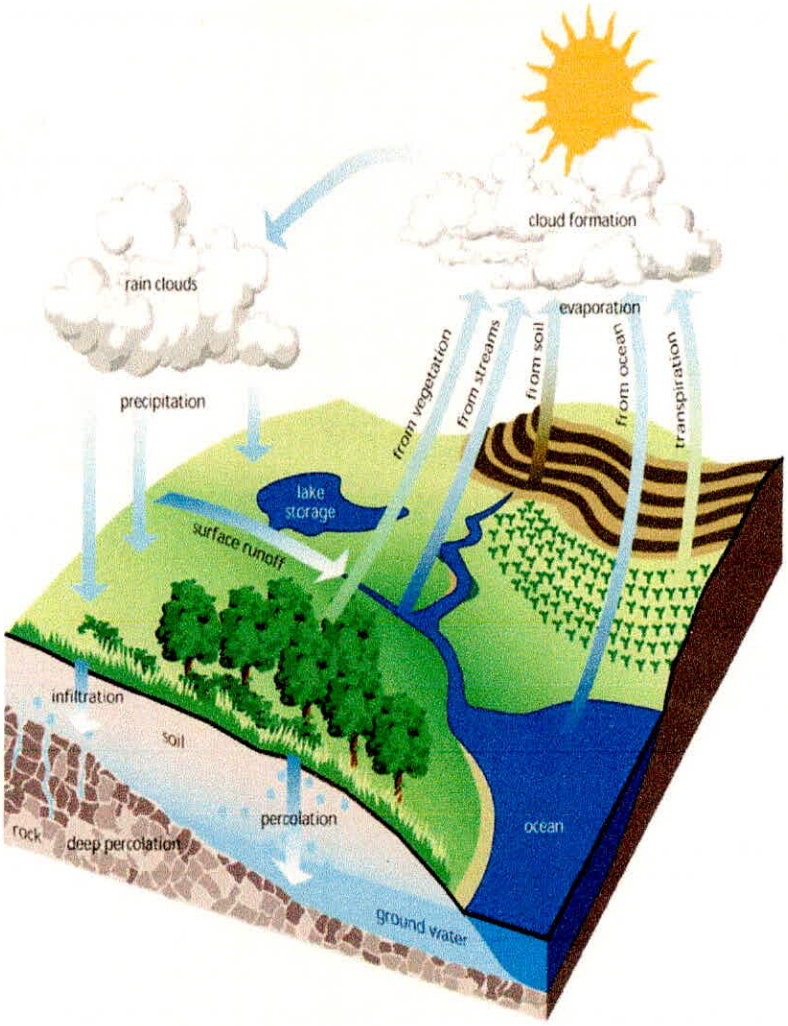



**Fig.1.1.1: Groundwater and Hydrological Cycle**

## Vertical Distribution of Groundwater:

The sub-surface occurrence of groundwater may be divided into zones of aeration and saturation. The zone of aeration consists of interstices occupied partially by water and partially by air. In the zone of saturation all interstices are filled with water, under hydrostatic pressure. One most of the land masses of the earth, a single zone of aeration overliesa single zone of saturation and extends upward to the ground surface, as shown in fig.1.1.2.

The zone or aeration contains vadose water. The zone of aeration may be further divided into soil water zone, intermediate vadose zone and capillary fringe. Soil water zone is the one, nearest to the ground surface. It is the zone where plants and trees on the surface get their moisture. The intermediate vadose zone is also known as sub-soil zone.

This has a bit more moisture than air content. Below the sub-soil zone lays the capillary fringe. In the capillary fringe, groundwater rises up due to capillary action which is possible due to the property of surface tension of water. In that level pore spaces are very low and thus water rises up to a certain height. In the zone of aeration, pore pressure is generally less than atmospheric pressure.

The saturated zone extends from the upper surface of saturationdown to underlying impermeable rock. In the absence of overlying impermeable strata, the water table, or phreatic surface, forms the upper surface of thezone of saturation. This is defined as the surface of atmospheric pressure and appears as the level at which water stands ina well penetrating the aquifer. Actually, saturation extends slightly above the water table due to capillary attraction; however, water is held here at less than atmospheric pressure. Water occurring in the zone of saturation is commonly referred to simply as groundwater, but the term phreatic water is also employ.

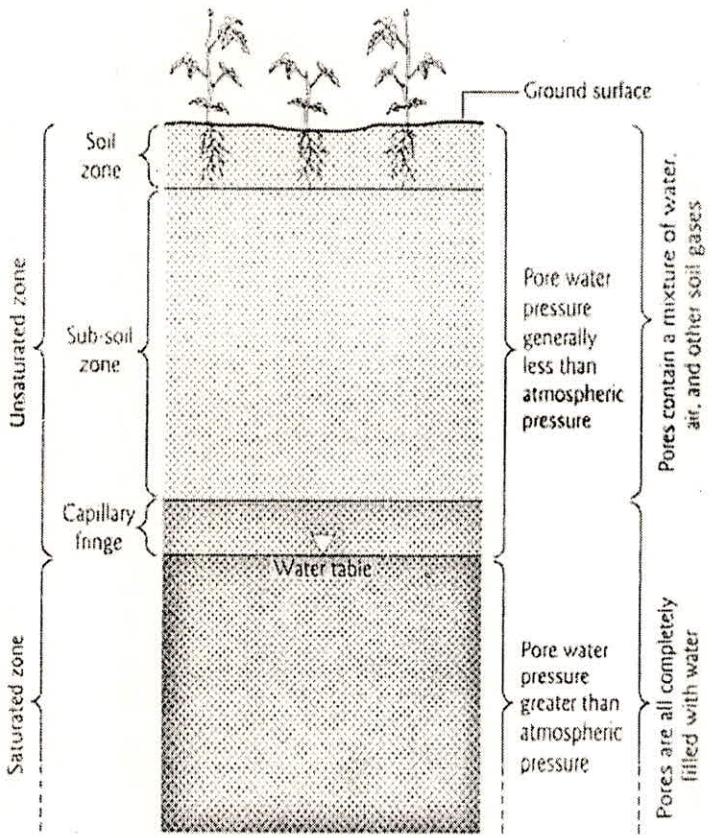



**Fig 1.1.2: Vertical Distribution of Groundwater**

## TYPES OF WATER BEARING FORMATIONS

Water bearing formations are defined as those formations which have sufficient amount of pore spaces that can help storing water. These formations also help in migration and movement of water particles through them due to the presence of inter-connected pore spaces. Such a property in a formation is called permeability. The measure of amount of pore spaces in a formation is called porosity. These two properties will be discussed in the later sections. Various types of water bearing formations include:

1. Aquifer 3.Aquiclude

2. Aquitard 4.Aquifuge

## AQUIFER

An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using water well. The study of water flow in aquifers and the characterization of aquifers are called hydrogeology. An aquifer is a ground-water reservoir composed of geologic units that are saturated with water and sufficiently permeable to yield water in a usable quantity to wells and springs. Sand and gravel deposits, sandstone, limestone, and fractured, crystalline rocks are examples of geological units that form aquifers. Aquifers provide two important functions:

1. They transmit groundwater from areas of recharge to areas of discharge, and
2. They provide a storage medium for usable quantities of groundwater.

## TYPES OF AQUIFERS

Depending upon the overlying and underlying rocks, aquifers can be classifies as confined or unconfined. A leaky aquifer is a combination of both of the above types.

### Unconfined Aquifer:

An unconfined aquifer is one in which a water table varies in undulating form and in slope, depending on areas of recharge and discharge, pumping from wells, and permeability. Rises and falls in the water table correspond to changes in the volume of water in storage within an aquifer. The upper aquifer in figure.1.1.3 is also unconfined.

Contour maps and profiles of the water table can be prepared from elevations of water in wells that tap the aquifer to determine the quantities of water available and their distribution and movement. A special case of an unconfined aquifer involves perched water bodies, as illustrated by figure.1.1.3. This occurs wherever a groundwater body is separated from the main groundwater by a relatively impermeable stratum of small areal extent and by the zone of aeration above the main body of groundwater. Clay lenses in sedimentary deposits often have shallow perched water bodies overlying them. Wells tapping these sources yield only temporary or small quantities of water.

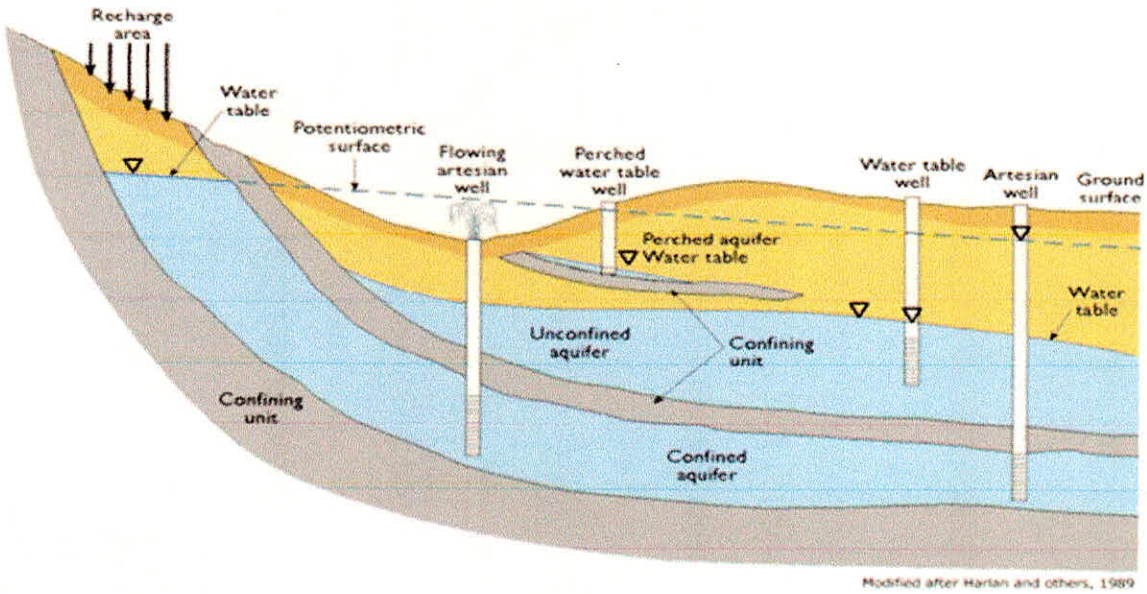



**Fig 1.1.3: Unconfined Aquifer**

**Confined Aquifer**:

Confined aquifers, also known as artesian or pressure aquifers, occur where groundwater is confined under pressure greater than atmospheric by overlying relatively impermeable strata. In a well penetrating such an aquifer, the waterlevel will rise above the bottom of the confining bed, as shown by the artesian and flowing wells of fig.1.1.3. Water enters a confined aquifer in an area where the confining bed rises to the surface; where the confining bed ends underground, the aquifer becomes unconfined. A region supplying water to a confined area is known as a recharge area; water may also enter by leakage through a confining bed. Rises and falls of water in wells penetrating confined aquifers result primarily from changes in pressure rather than changes in storage volumes. Hence, confined aquifers

display only small changes in storage and serve primarily as conduitsfor conveying water from recharge areas to locations of natural or artificial discharge.

**Leaky Aquifer:**Aquifers that are completely confined or unconfined occur less frequently than do leaky, or semi-confined, aquifers. These are a common feature in alluvial valleys, plains, or former lake basins where a permeable stratum isoverlain or underlain by a semi-pervious aquitard or semi-confining layer. Pumping from a wellin aleaky aquifer removes water in two ways: by horizontal flow within the aquifer and by vertical flow through the aquitard into the aquifer. (Fig.1.1.4).

**Aquitard**

An aquitard is a partly permeable geologic formation. It transmits water at such as lowrate that the yield is insufficient. Pumping by wells is not possible. For example, sand lenses in a clay formation will form an aquitard.

**Aquiclude**

An aquiclude iscomposed of rock or sedimentthat acts as a barrier to groundwater flow. Aquicludes are made up of low porosity and low permeability rock/sediment such as shale or clay. Aquicludes have normally good storage capacity but low transmitting capacity.

**Aquifuge**

An aquifer is a geologic formation which doesn't have interconnected pores. It is neither porous nor permeable. Thus, it can neither store water transmit it. Examples of aquifer are rocks like basalt, granite, etc. without fissures.

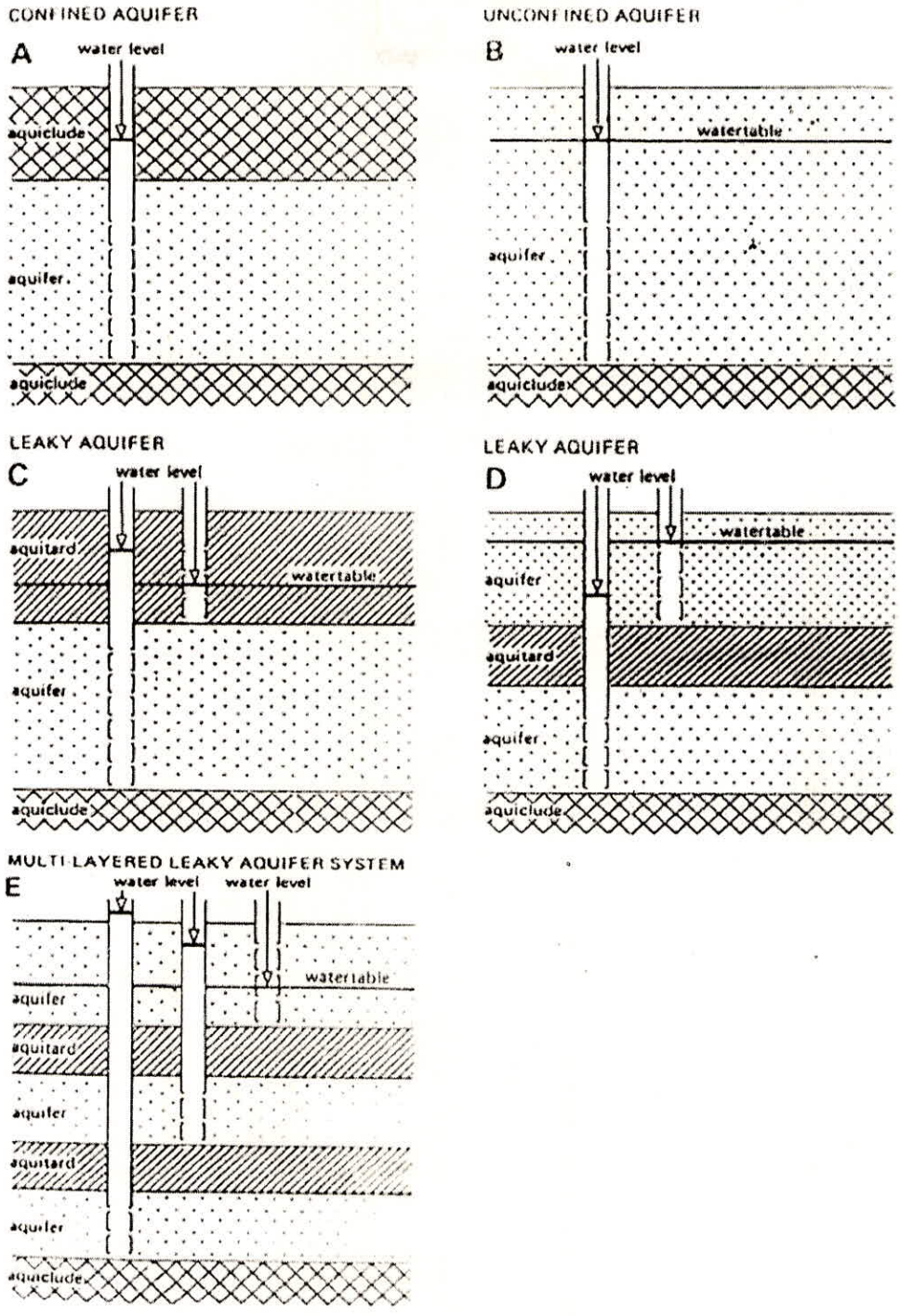



**Fig 1.1.4 Ground water levels**

## MOVEMENT OF GROUNDWATER

On the surface, movement of water seems quite a simple phenomenon, where water flows under the action of gravity. However, under the surface, the movement is quite complex. As water travels through the interstices of the rocks number of factors come to play.

The basic principle says that as surface water moves from a point of higher elevation to that of lower elevation, subsurface water travels from points of higher hydraulic head to those of lower hydraulic head. Hydraulic head is nothing but the specific measurement of liquid pressure above a geodetic datum. So basically we can say that water moves from a point of higher pressure to a point of lower pressure.

Various rock properties also affect the movement of groundwater. They are

1. Porosity
2. Specific Yield
3. Specific Retention
4. Coefficient of permeability
5. Transmissibility
6. Specific Storage
7. Storage Coefficient

**1. POROSITY.** Porosity (n) is the percentage ofrock or soil that is void of material. The larger the pore space or the greater their number, the higher the porosity and the larger the

$$n = \frac{V_v}{V} \times 100\%$$

Where,

$n$ is the porosity (percentage)
$V_v$ is the volume of void space in a unit volume of earth materials ($L^3$, $cm^3$ or $m^3$)
$V$ is the unit volume of earth material, including both voids and solids ($L^3$, $cm^3$ or $m^3$)

water-holding capacity. It is defined mathematically by the equation,

In sediments or sedimentary rocks the porosity depends on grain size, the shape of the grains, the degree of sorting and the degree of cementation. In rocks, the porosity depends upon the extent, spacing and pattern of cracks and fractures.

The porosity of well-rounded sediments, which have been sorted so that they are all about the same size, is independent of particle size, depending upon the packing. Well-rounded course-

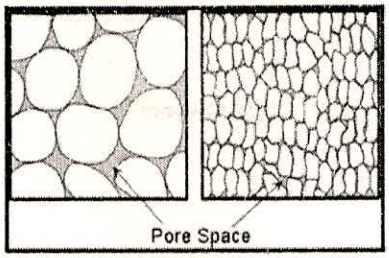



**Fig.1.1.5 Porosity of well-rounded sediments**

Grained sediments usually have higher porosity than fine-grained sediments; because the grains don't fit together well (see Fig.1.1.5)

In igneous and metamorphic rocks porosity is usually low because the minerals tend to be intergroup, leaving little free space. Higher fractured igneous and metamorphic rocks, however, could have high secondary porosity. Since cements tend to fill in the pore space, highly cemented sedimentary rocks have lower porosity (see Fig.1.1.6).

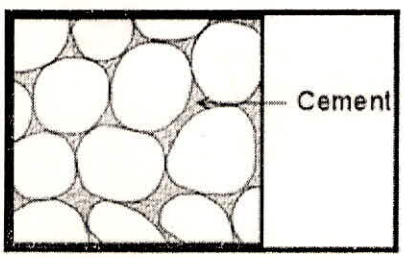



**Fig 1.1.6 Porosity of highly cemented sedimentary rocks**

Poorly sorted sediments (sediments contains a mixture of grain sizes) usually have lower porosity because the fine-grained fragments tend to fill the open spaces (see Fig.1.1.7). The porosity of sediments is affected by the shape of the grains. Well-rounded grains may be almost perfect spheres, but many grains are very irregular. They can be shaped like rods, disks, or books. Sphere-shaped grains will pack more tightly and have less porosity than particles of other shapes. The fabric or orientation of the particles, if they are not spheres, also influences porosity.

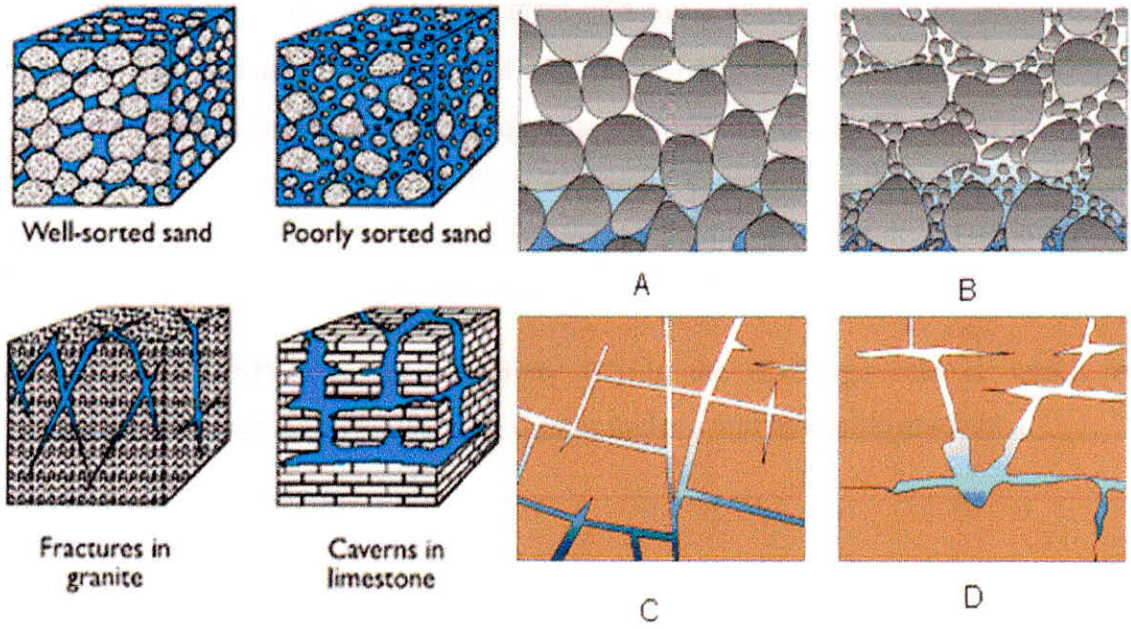



**Fig.1.1.7 Tendency of fine-grained fragments to fill the open spaces**

**2. SPECIFIC YIELD.** Specific yield ($S_y$) is the ratio of the volume of water that drains from a saturated rock owing to the attraction of gravity (or by pumping from wells) to the total volume of the saturated aquifer. It is defined mathematically by the equation:

$$S_y = \frac{V_w}{V} \times 100\%$$

where,

$V_w$ is the volume of water in a unit volume of earth materials ($L^3$, $cm^3$ or $m^3$)
V is the unit volume of earth material, including both voids and solids ($L^3$, $cm^3$ or $m^3$

**3. SPECIFIC RETENTION.** Specific retention ($S_r$) is the ratio of the volume of water that can't be drained out to the total volume of the saturated aquifer. Since the specific yield represents the volume of water that a rock will yield by gravity drainage, hence the specific

$$n = S_r + S_y$$

retention is the remainder. The sum of the two,equals porosity.

**4. PERMEABILITY AND HYDRAULIC CONDUCTIVITY.** Permeability is the case with which water can flow in a soil mass or a rock. The coefficient of permeability (K) is equal to the discharge ($m^3/s$) per unit area ($m^2$) of soil mass under unit hydraulic gradient. Because the discharge per unit area equals to the velocity, the coefficient of permeability has the dimension of the velocity [L/T]. It is usually expressed as cm/s, m/s, m/day, etc. The coefficient of permeability is also called hydraulic conductivity. Usage of hydraulic conductivity is given under the next heading Darcy's law.

**5. TRANSMISSIVITY.** Transmissivity (T) is the discharge rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

T= Kb (confined aquifer)

T=Kh (unconfined aquifer)

b is the saturated thickness of the aquifer. b is equal to the depth of a confined aquifer. It is equal to the average thickness of the saturated zone of an unconfined aquifer.

**6. SPECIFIC STORAGE.** Specific Storage ($S_s$) is the amount of water per unit volume of a saturated formation that is stored or expelled from storage owing to compressibility of the mineral skeleton and the pore water per unit change in head. This is also called the elastic storage coefficient. The concept can be applied to both aquifers and confining units. The

$$S_s = \rho_w g(\alpha + n\beta)$$

where
- $\rho_w$ is the density of the water ($M/L^3$; $Kg/m^3$)
- $g$ is the acceleration of gravity ($L/T^2$; $m/s^2$)
- $\alpha$ is the compressibility of the aquifer skeleton ($1/(M/LT^2)$; $m^2/N$)
- $n$ is the porosity
- $\beta$ is the compressibility of water ($1/(M/LT^2)$; $m^2/N$)

specific storage is given by the expression (Jacob 1940, 1950; cooper 1966):

**7. STORAGE COEFFICIENT.** Storage coefficient (S) is the volume of water released from storage, or taken into storage, per unit of aquifer storage area per unit change in head. The storage coefficient is also called **Stativity**. The storage coefficient is a dimensionless as it is the ratio of the volume of water released from original unit volume.

The water-yielding capacity of an aquifer can be expressed in terms of its storage coefficient. In unconfined aquifers, Stativity is the same as the specific yield of the aquifer. In confined aquifer, Stativity is the result of compression of the aquifer and expansion of the confined water when the head (pressure) is reduced during pumping.

Ground water in its natural state is invariably moving. The flow of groundwater is described by Darcy's law.

## SPECIFIC DISCHARGE AND AVERAGE LINEAR VELOCITY

In another form, Darcy's law can be expressed as the discharge per cross sectional area as follows:

$$q_s = \frac{Q_s}{A} = -K_s \frac{dh}{ds}$$

The quantity $q_s$ is generally known as the specific discharge and are sometimes called the Darcy velocity. To help understand the physical meaning of $q_s$, think of an imaginary square panel perpendicular to the s direction as shown in Fig.1.1.8.

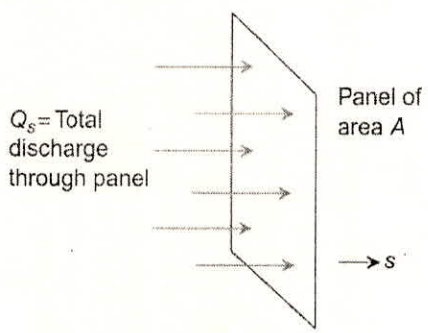



**Fig.1.1.8 Specific Discharge and Average Linear Velocity**

The flow through this panel is $Q_s$ and the area of the panel is A. The specific discharge $q_s$ is the ratio of discharge to area $Q_s/A$, as the panel area shrinks to a very small size. Specific discharge has dimensions [L/T] like a velocity, but it means something a bit different than the average groundwater velocity.

If water could own through all of the area A of the cross-section, the specific discharge would represent the average velocity of water movement through the cross-section. In a subsurface medium, however, only a fraction of the cross-section is available for water to move through, so the average velocity of water through the pores is higher than the specific discharge. The average linear velocity $v_s$ of water motion are directly proportional to the specie discharge and inversely proportional to the effective porosity $n_e$:

$$\bar{v}_s = \frac{q_s}{n_e}$$

## IMPORTANCE OF GROUNDWATER

The importance of groundwater for the existence of human society cannot be overemphasized. Groundwater is the major source of drinking water in both urban and rural India. Besides, it is an important source of water for the agricultural and the industrial sector. Water utilization projections for 2000 put the groundwater usage at about 50%. Being an important and integral part of the hydrological cycle, its availability depends on the rainfall and recharge conditions. Till recently it had been considered a dependable source of uncontaminated water.

The demand for water has increased over the years and this has led to water scarcity in many parts of the world. The situation is aggravated by the problem of water pollution or contamination. India is heading towards a freshwater crisis mainly due to improper management of water resources and environmental degradation, which has led to a lack of access to safe water supply to millions of people. This freshwater crisis is already evident in many parts of India, varying in scale and intensity depending mainly on the time of the year.

Groundwater crisis is not the result of natural factors; it has been caused by human actions. During the past two decades, the water level in several parts of the country has been falling rapidly due to an increase in extraction. The number of wells drilled for irrigation of both food and cash crops have rapidly and indiscriminately increased. India's rapidly rising population and changing lifestyles has also increased the domestic need for water. The water requirement for the industry also shows an overall increase. Intense competition among user's agriculture, industry, and domestic sectors is driving the groundwater table lower. The quality of groundwater is getting severely affected because of the widespread pollution of surface

water. Besides, discharge of untreated waste water through bores and leachate from unscientific disposal of solid wastes also contaminates groundwater, thereby reducing the quality of fresh water resources.

As far as the quality of groundwater is concerned, many states in the country have been identified as endemic to fluorosis due to abundance in naturally occurring fluoride-bearing minerals. These are Andhra Pradesh, Gujarat, Haryana, Orissa, Punjab, Rajasthan, TamilNadu, Uttar Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Bihar, and Delhi. Nearly half million people in India suffer from ailments due to excess of fluoride in drinking water. In some districts of Assam and Orissa, groundwater has high iron content. About 31% of the total area of Rajasthan comes under saline groundwater. Groundwater is saline in almost all of the Bhakra Canal in Punjab and the lift canal system in south-western Haryana. Similarly high levels of arsenic in groundwater have been reported in the shallow aquifers in some districts of West Bengal. Certain places in Haryana, Gujarat, and Andhra Pradesh were also found to have dangerously high levels of mercury.

**Causes of groundwater depletion and contamination**

Groundwater is an integral part of the environment, and hence cannot be looked upon in isolation. There has been a lack of adequate attention to water conservation, efficiency in water use, water re-use, groundwater recharge, and ecosystem sustainability. An uncontrolled use of the bore well technology has led to the extraction of groundwater at such a high rate that often recharge is not sufficient. The causes of low water availability in many regions are also directly linked to the reducing forest cover and soil degradation.

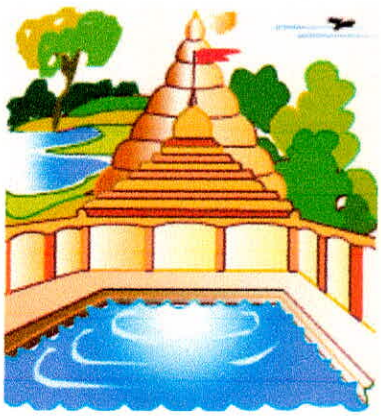
Pollution of groundwater resources has become a major problem today. The pollution of air, water, and land has an effect on the pollution and contamination of groundwater. The solid, liquid, and the gaseous waste that is generated, if not treated properly, results in pollution of the environment; this affects groundwater too due to the hydraulic connectivity in the hydrological cycle. For example, when the air is polluted, rainfall will settle many pollutants on the ground, which can then seep into and contaminate the groundwater resources. Water extraction without proper recharge and leaching of pollutants from pesticides and fertilizers into the aquifers has polluted groundwater supplies. In addition, leachates from agriculture, industrial waste, and the municipal solid waste have also polluted surface- and ground-water. Some 45 million people

the world over are affected by water pollution marked by excess fluoride, arsenic, iron, or the ingress of salt water.

**What can and should be done**

It is important to realize that groundwater is not a resource that could be utilized unmindfully simply because it is available in abundant quantities. Problems and issues such as water logging, salinity, agricultural toxins, and industrial effluents, all need to be properly looked into.

Other than legislation and checks to conserve and improve the quality of groundwater, society itself plays a very important role. During the last decade there has been a rising awareness among the common people on the need for conservation and development of groundwater. Water use has to be integrated effectively with water regeneration, as was done in many traditional technologies.



Renovation of forest tanks in drought-prone regions will have a significant impact on wildlife and forest cover. Similarly, in some urban cities there is a need to regenerate groundwater aquifers because of the high degree of dependence on them for drinking water. Rainwater harvesting schemes have been taken up in many cities and even made compulsory in some of them. Temple tanks need to be renovated and urban wetlands protected. All these will contribute to a rise in the groundwater level and a reduction of salt water ingress. Community awareness and management of freshwater resources should be enhanced. The government should implement effective groundwater legislation and regulations through self-regulation by communities and local institutions. External support agencies should support freshwater resource management. Environmental restoration should be promoted along with household water security.

No single action whether community based, legislation, traditional water harvesting systems, or reliance on market forces will in itself alleviate the crisis in India. The effective answer to the freshwater crisis is to integrate conservation and development activities – from water extraction to water management at the local level; making communities aware and involving them fully is therefore critical for success. All this will ultimately pave the way for combining conservation of the environment with the basic needs of people.

In India, the Water (Prevention and Control) Act was passed by the Parliament in 1974, and by 1990 all the states adopted the act. In 1986, the Environment Protection Act was passed by the Parliament. Under both these acts, the states and the central government developed environmental norms for air emissions and waste water discharge for different types of sources.

(Web source: edugreen.teri.res.in/explore/water/ground.htm)

## 1.2: SEAWATER INTRUSION

Almost two thirds of the world's population lives within 400 km of the ocean shoreline just over half live within 200km, an area only taking up 10% of the earth's surface. Most of the coastal regions rely on groundwater as their main source of fresh water for domestic, industrial and agricultural purposes. As the world's population continuous to grow at an alarming rate, fresh water supplies are constantly being depleted, bring with it issues such as seawater intrusion and increasing the importance of groundwater monitoring, management and conservation.Seawater intrusion is a major concern commonly found in coastal aquifer around the world.

**The movement of seawater into a fresh water aquifer is known as seawater intrusion, which can lead to contamination of drinking water sources and other consequences**

Fresh water is slightly less dense (lighter) than salt water, which tends it to float on top of the salt water when both fluids are present in an aquifer. The relationship based on density difference between saltwater and fresh water is used to estimate the depth to saltwater based on the thickness of the freshwater zone above sea level. The relationship is known as the **Ghyben-Herzberg relation.**

This happens primarily because seawater is denser than fresh water, and so a column of seawater exerts a higher pressure than a column of fresh water of the same height. Under natural conditions, seawater intrusion is also affected by tides. The tides change the shape of the wedge and can also cause a wider mixing zone between the seawater and fresh groundwater. The theoretical interface actually occurs at a depth below sea level that is 40 times the height of fresh water above sea level; this relationship is called the Ghyben-Herzberg relation, after the two European scientists who independently recognized it at the turn of the century. In practice geological variability makes the relationship more complex.

When groundwater is pumped from a coastal aquifer the fresh-water level is lowered and the sea intrudes further into the aquifer. With excessive pumping the natural hydraulic gradient towards the sea may be reversed and the intrusion can then extend to the pumping borehole which becomes saline.

**Ghyben-Herzberg Relation:**

The first physical formulations of saltwater intrusion were made by W. Badon-Ghijben (1888, 1889) and A. Herzberg (1901), thus called the Ghyben-Herzberg relation. They derived analytical solutions to approximate the intrusion behaviour, which are based on a number of assumptions that do not hold in all field cases.

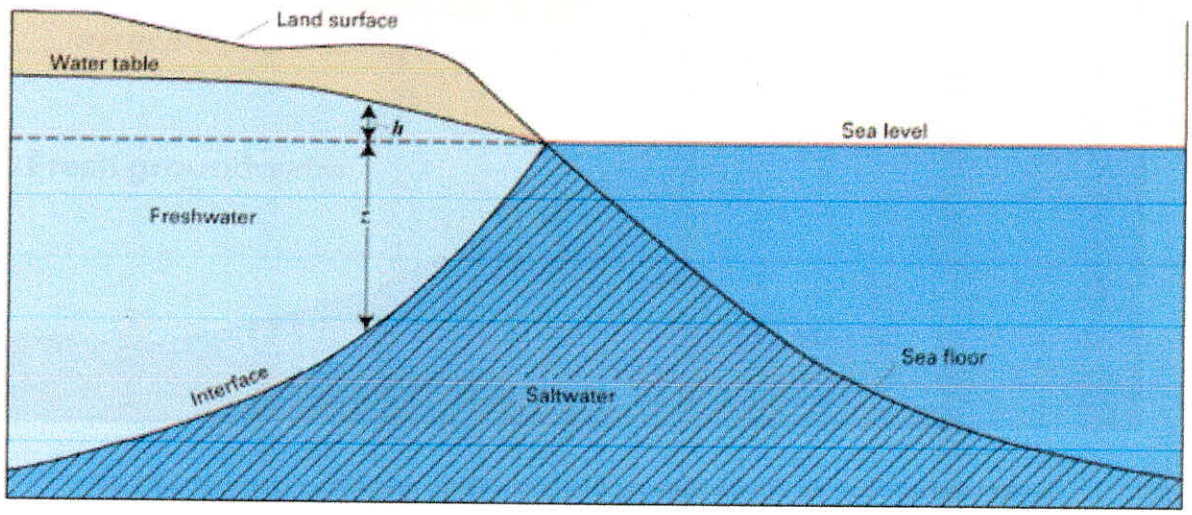



**Fig.1.2.1 Ghyben-Herzberg relation**

The Fig.1.2.1 shows the Ghyben-Herzberg relation. In the equation,

$$z = \frac{\rho_f}{(\rho_s - \rho_f)} h$$

The thickness of the freshwater zone above sea level is represented as and that below sea level is represented as. The two thicknesses and, are related by and where is the density of freshwater and is the density of saltwater.

Freshwater has a density of about 1.000 grams per cubic centimetre (g/cm$^3$) at 20 °C, whereas that of seawater is about 1.025 g/cm$^3$. The equation can be simplified to,

The Ghyben-Herzberg ratio states, for every foot of fresh water in an unconfined aquifer above sea level, there will be forty feet of fresh water in the aquifer below sea level.

$$z = 40h$$

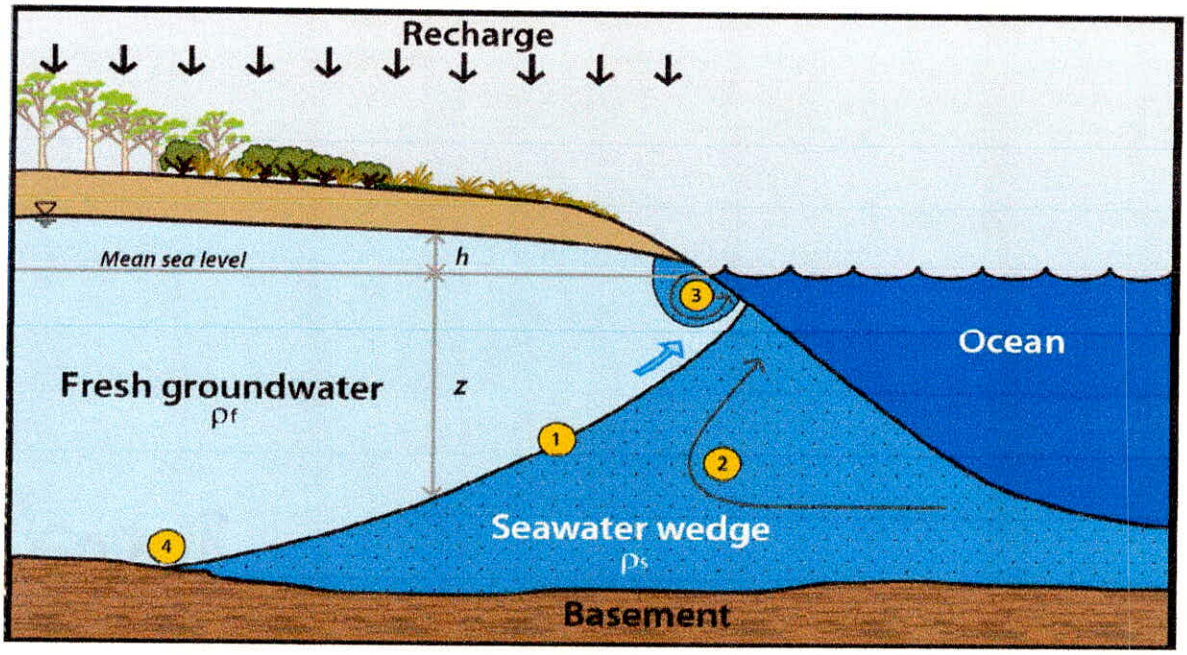



**Fig.1.2.2 Natural equilibrium of seawater and groundwater in an undisturbed system**

The image above shows the natural equilibrium of seawater and groundwater in an undisturbed system. Fig.1.2.2 shows (1) marks the interface between seawater and groundwater; (2) shows movement of water affected by density, while (3) is movement driven by the tide. Figure (4) shows the furthest extent of seawater intrusion.

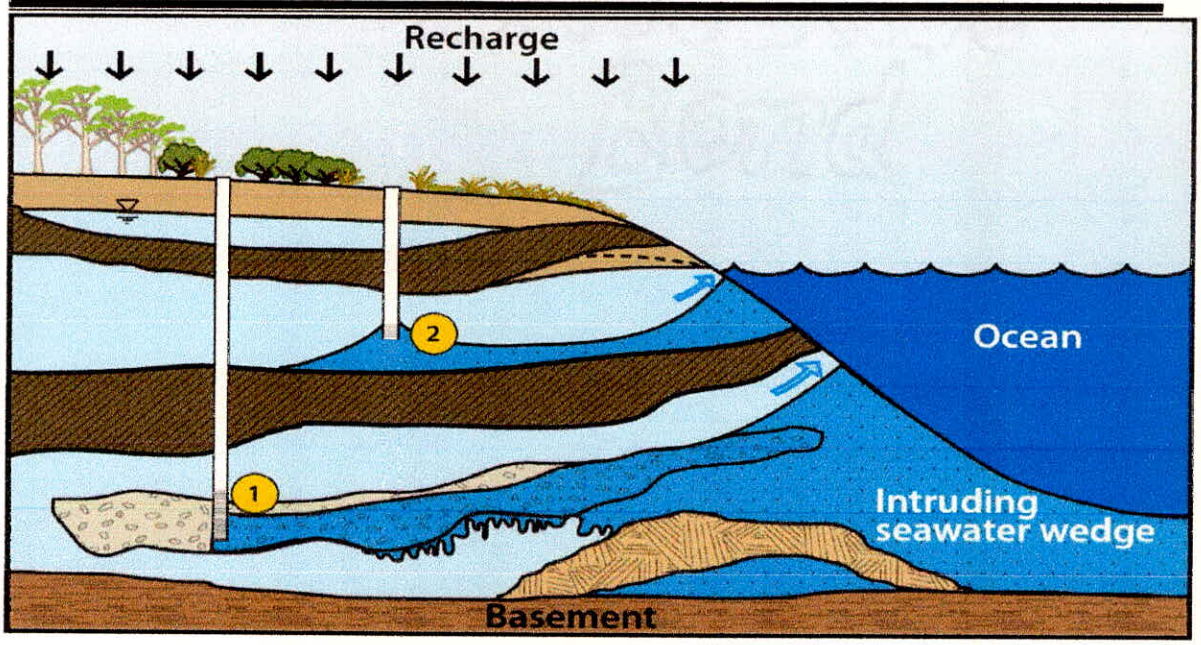



**Fig.1.2.3 Seawater intrusion occurring in a more complex aquifer with human activity contributing**

The image above shows seawater intrusion occurring in a more complex aquifer with human activity contributing. The fig.1.2.3 shows (1) seawater moving preferentially through high-permeability layers in the ground, and (2) excessive pumping drawing seawater upwards, causing the bore to become contaminated.

**Causes of sea water intrusion:**

**Rising of sea water level:**

Sea level raise caused by global warming as become a route cause, pressure from increasing the quantity of sea water that many will try to enter the fresh water aquifer.

**High consumption of fresh water:**

Excessive consumption of fresh water due to development caused a shortage of fresh water in that area and cause the waters invaded by sea water.

**Oil drilling:**

Oil ring usually use oil pipeline under the ground to deliver the oil from drilling site to storage tanks on the beach, as the result and the easier to sea water to insult the fresh water.

**Lack of rain:**

Lack of rain causes replacement of fresh water consumption was slow while the uses are increased. In this case it will reduce the amount of fresh water in the ground and it will be replaced by seawater.

**Agriculture:**

Agriculture is human activity that required lot amount of fresh water, it will not suitable in areas that isnear the sea.

**Pumping:**

Pumping of fresh water from an aquifer reduces the water pressure and intensifies the effects, drawing seawater into new areas. When fresh water levels drop, seawater intrusion can proceed inland, reaching the pumped well.

**ILL- effects of seawater intrusion:**

Pumping groundwater at a faster rate than it can be recharged can have some negative effects of the environment and the people who make use of the water.

**Lowering of the water table:**

The most severe consequence of excessive groundwater pumping is that the water table, below which the ground is saturated with water, can be lowered. For water to be withdrawn from the ground, water must be pumped from a well that reaches below the water table. If ground water levels decline too far, then the well owner might have to deepen the well, drill a new well, or, at least, attempt to lower the pump. Also, as water levels declined, the rate of water the well can yield may decline.

**Increased costs for the user:**

As the depth to water increases, the water must be lifted higher to reach the land surface. If pumps are used to lift the water more energy is required to drive the pump. Using the well can become prohibitively expensive.

**Reduction of water in streams and lakes:**

There is more of an interaction between the water in lakes and rivers and ground water than most people think. Some, and often a great deal, of the water flowing in rivers come from seepage of groundwater into the stream bed. Groundwater contributes to streams in most physiographic and climatic settings. The proportion of stream water that comes from groundwater in flow varies according to a region's geography, geology and climate.

**Land subsidence:**

The basic cause of land subsidence is loss of support below ground. In other words, sometimes when water is taken out of the soil, soil collapse, compacts, and drops. This depends on a number of factors, such as the type of soil and rock below the surface. Land subsidence is most often caused by human activities, mainly from the removal of subsurface water.

**Deterioration of water quality:**

One water-quality threat to fresh groundwater supplies is contamination from seawater intrusion. All of the water in the ground is not fresh water; much of the very deep groundwater and water below oceans is saline. In fact, an estimated 3.1 million cubic miles of saline ground water exists compared to about 2.6 million cubic miles of fresh groundwater. Under natural conditions the boundary between the fresh water and sea water tends to be relatively stable, but pumping can cause seawater to migrate inland and upward, resulting in seawater contamination of the water supply.

**Mechanism of seawater intrusion:**

Seawater intrusion is the movement of seawater into the fresh water aquifers.

Most often, it is caused by ground-water pumping from coastal wells, or from construction of navigation channels or oil field canals.

Seawater intrusion occurs in virtually all costal aquifers, where they are in hydraulic continuity with seawater.

The channels and canals provide conduits for salt water to be brought into fresh water marshes. Seawater can also occur as the result of a natural process like a storm surge from a hurricane.

**1.3: Conventional techniques and isotopes in groundwater analysis:**

Conventional techniques in groundwater analysis most of the conventional techniques used for groundwater analysis are basically to assess water quality. Groundwater contains salts in solution that are dissolved locally are during past movement of water. Quality required is depended on the purposes of use to establish quality criteria measures of chemical and physical constituents.

**Chemical analysis:**

The complete chemical analysis of groundwater sample includes the determination of concentration of inorganic constituents present.The analysis includes the measurement of electrical conductivity and bi-carbonates.

**Isotopes in groundwater analysis:**

Isotopes are different species of the same element. All though having same atomic number they differ in massnumber due to presence of different number of neutrons in the nucleus of the atomic shell. Environmental isotopes are the naturally occurring isotopes of element found in abundance in the environment. Examples are H, C, N, O and S. They are principle elements of hydrological, geological and biological systems. They are isotopes of lighter elements. Has consequence relative mass between their isotopes are large importing measurable fractionation during physical and chemical process. They are not only used to trace groundwater provenience but also recharged process, groundwater quality sub-surface process geo-chemical reactions and evaluation, rock water interactions and reaction rates. Broadly environmental isotopes are of two different types stable and unstable isotopes.

**Unstable isotopes:**

Naturally occurring radioactive isotopes provide information about groundwater's age, which refers to the last time water, was in contact with the atmosphere.

Once the recharge area has been established using the isotopes fingerprinting methods, radio isotopes may be used to element how long it took for a parcel of groundwater to travel from its recharge area to the measurement point. For young groundwater, the best dating method is one that measures the relative abundance of tritium ($^3H$) and Helium ($^3He$). Tritium is a radioactive isotope ofhydrogen that decays to $^3He$ with the of life of 12.4 years. The amount of $^3He$ from the decay of tritium is measure along with the amount of tritium remaining in the water. The sum is equal to the amount of tritium that was present at the time of recharge. The $^3H$-$^3He$ dating method is remarkably accurate for groundwater up to 40 years old with an age resolution of + or – one year. The ages of older groundwater can be measured in several ways. One is by measuring the carbon-14 ($^{14}C$) dissolved in the water. Carbon-14 decays at the known rate with the half-life of 3230 years. Providing the useful dating method,the groundwater less than 40000 years old. Another method uses the isotope Helium-4 which is produced continuously deep within the earth by the radioactive decay of uranium and thorium relative age relationships determined from the $^4He$ groundwater are a valuable implement in $^{14}C$ age determination.

**1.4: Stable isotopes and their application in groundwater studies:**

**Stable isotopes:**

All waters have finger prints of naturally occurring isotopes that provide information about their origin. Among the most power full and cost effective finger printing tools are the ratio of stable isotopes are hydrogen-deuterium to hydrogen (D/H) - and of oxygen-18 to oxygen-16 ($^{18}O/^{16}O$). For example D/H and $^{16}O$ ratios in precipitation vary according to elevation and distance from the ocean. An altitude different of 250m (820') produces a clear and measurable change in the two ratios, which is preserved once the precipitation, infiltrates to the aquifer. While some mixing of water in the aquifer is inevitable, aquifers are typically not homogeneous. Layers of heavy clay retread the movement of groundwater within the aquifer and often serve to keep water from different sources distend from each other. Thus, scientists can use D/H and $^{18}O/^{16}O$ ratios to determine the recharge location for the groundwater and to discriminate among multiple water sources within aquifers.

As the name suggests, stable isotopes don't spontaneously disintegrate by any known mode of decay. Basically stable isotopes of interest for analysis are those which are abundant in the atmosphere. They are used mainly for flow system tracing and climatic reconstruction.

They are useful for determining source, movement, quality, evaluation and age using their mass fractionation due to physical processes. For instance the stable isotopic composition of water is modified by meteoric processes, and so the recharge water's in the particular environment will have a characteristics isotopic signature. This signature then severs as a natural tracer for the provenance of groundwater.

The varous stable isotopes of elements found in the nature those of oxygen and hydrogen are used most commonly, typically one isotopes dominates that rest in terms of relative abundances. Stable isotopes are measure as the ratio of two most abundant isotope of a given element. For example oxygen is the ratio of $^{18}O$ with the terrestrial abundance of 0.204% to common $^{16}O$ which represents 99.796 of terrestrial oxygen. Thus the $^{18}O/^{16}O$ ratio is about 0.00204.

**The isotope ratio:**

The relative abundance of two isotopes a and b of element X can be expressed as an isotopic ratio, $^{a}R$:

$$^{a}R = \frac{^{a}X}{^{b}X}$$

By convention, the more abundant isotope is placed in the denominator. This notation is not particularly helpful in itself however, as changes in R could result from changes in either $^{a}X$ or $^{b}X$. It is however the basis for several expressions that are very useful.

**Fractional abundance, $^{a}F$:**

$$^{a}F = \frac{^{a}X}{\left(^{a}X + ^{b}X\right)}$$

This expression is particularly useful in artificially enriched systems where the ratio of $^{a}X$ to $^{b}X$ is increased by the intentional addition of a pure source of one of the two isotopes (usually the heavy isotope). The pure source is referred to as a spike, the process of adding the source as "spiking" a sample. Spikes allow us to monitor the movement of isotopes from one reservoir to another in response to one of more chemical reactions.

**Relationship between $^{a}R$ and $^{a}F$:**

Note that

$$^{a}F = \frac{^{a}R}{\left(1+^{a}R\right)}$$

or alternatively,

$$^{a}R = \frac{^{a}F}{\left(1-^{a}F\right)}$$

**The delta notation, $d^{a}X$.**

In many natural systems, the isotopic ratio $^{a}R$ exhibits variability in the range of the third to fifth decimal place. Numbers this small are best presented in terms of per mil, or parts per thousand (%). The ratio in a sample, denoted here as $^{a}R_{x}$ can be expressed relative to the isotopic ratio of a standard $^{a}R_{std}$ using a difference relationship knows as the delta notation ($d^{a}X$):

$$\delta^{a}X = \left(\frac{^{a}R_{x} - ^{a}R_{std}}{^{a}R_{std}}\right) \times 1000$$

or alternatively,

$$\delta^{a}X = \left(\frac{^{a}R_{x}}{^{a}R_{std}} - 1\right) \times 1000$$

**Change of isotopic reference scale:**

$$\delta_{x-a} = \left[\left(\frac{\delta_{b-a}}{1000} + 1\right)\left(\frac{\delta_{x-a}}{1000} + 1\right) - 1\right] \times 1000$$

This relationship can be used to convert an isotopic value from one reference scale to another reference scale.

# Chapter-2

# FIELD WORK

# CHAPTER 2

# 2. FIELD WORK

## 2.1 STUDY AREA

The area studied for seawater intrusion was the coastal area of Karnataka. Karnataka is the eighth largest State in India covering geographical area of 191791sq.km. It lies between north latitudes 11° to 18° and, east longitudes 74° to 78°. The State is bounded on the west by about 400 km long coastline of Arabian Sea,Deccan Plateau to the west, Goa and Maharashtra in the north, Tamil Nadu and Kerala in the south and Andhra Pradesh to the east. Administratively, the State is divided into 30 districts..

**Geography of Karnataka**

- Area - 191791 square kilometers.
- Latitude - 74° to 78° East.
- Longitude - 11° to 18° North.
- Boundaries - Deccan Plateau to the west, Goa and Maharashtra in the north, Tamil Nadu and Kerala in the south and Andhra Pradesh to the east.
- Population -61,130,704.
- Rate of Literacy – 75.4%
- Number of Districts - 30.

**Coastal regions in Karnataka Geographical division**

Karnataka Coastal Region - Karnataka Coastal Region forms an important part of Karnataka geography. The region covers the Western Ghats, edges of the Karnataka Plateau, Uttara Kannada districts, Udupi and DakshinaKannada.

**Physiography**

The narrow Coastal plain along the west coast running about 300 km from Karwar in the north to Mangalore in south. The tract is generally very narrow reaching maximum width of about 40 km at places. The general elevation of the ground varies between 0 to 200 m above mean sea level. The rivers draining the area have a westerly course.

**Drainage**

The state is drained by the rivers Krishna, Cauvery, Godavari, West flowing minor rivers, Palar, Pennar and Ponnaiyar (Fig.2.1.1).

The remaining area is drained by the **west flowing rivers** such as Kalinadi, Netravathi, Sharavathi, Sita and Swarna etc. Sharavathi is a major river which originates and flows entirely within the state of Karnataka in India. It is the one of the few westward flowing rivers of India and a major part of the river basin lies in the Western Ghats. The famous jog falls, located about 24km from sagara, are formed by this river the river itself and the region around it are rich in biodiversity and home too many rare species of flora and fauna.

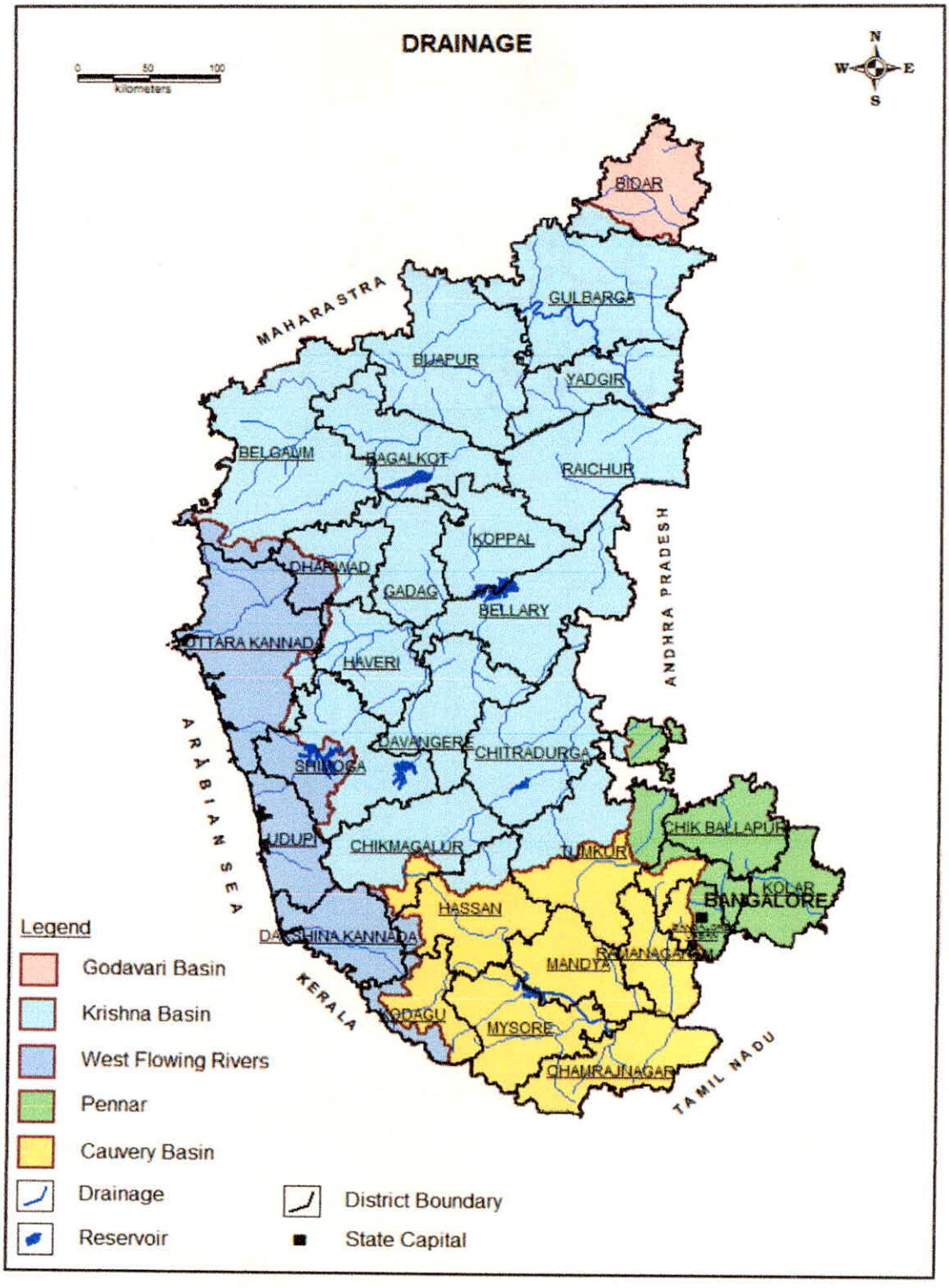



**Fig.2.1.1 Karnataka state drainage map**

**Coastline of Karnataka**

Karnataka's coastline called Karavali stretches 300 km between Mangalore in Dakshina Kannada district and Karwar in Uttara Kannada district. The coastline of Karnataka has been along the eastern shore of Arabian Sea. Karnataka has one major and ten minor ports in this coastal belt. Kali, Belekeri, Gangavali, Aghanashini, Sharavathi, Sharabi, Kollur, Gangolli, Sitanadi, Gurpur and Netravati are the important rivers in this belt which empty into the Arabian sea. Sea erosion, migration of river mouths, siltation of ports and harbors are some of the problems common to this belt. There are three districts that has coastline,they are Dakshinakannada, Udupi,Uttarakannada.

**Soil types**

Eleven groups of soil orders are found in Karnataka viz. Entisols, Inceptisols, Mollisols, Spodosols, Alfisols, Ultisols, Oxisols, Aridisols, Vertisols, Andisols and Histosols. Depending on the agricultural capability of the soil, the soil types are divided into six types viz., Red, lateritic (lateritic soil is found in bidar and kolar district), black, alluvio-colluvial, forest and coastal soils. The common types of soil groups found in Karnataka are:

Red soils: Red gravelly loam soil, Red loam soil, Red gravelly clay soil, Red clay soil

Lateritic soils: Lateritic gravelly soil, Lateritic soil

Black soils: Deep black soil, Medium deep black soil, Shallow black soil

Alluvio-Colluvial Soils: Non-saline, saline and sodic

Forest soils: Brown forest soil

**Coastal soils: Coastal laterite soil, Coastal alluvial soil.**

**Study area:** Coastal Karnataka

**Total coast length:** 300km

**Names of Districts in the direction from North to south (total 3 districts):** Uttara Kannada, udupi, dakshina Kannada

**Coastal Talukas and the Coastal District population**

| Coastal Districts | Talukas | District Population (2011) |
|---|---|---|
| Uttara kannada | Sirsi, honnavara, bhatkal, karwar, kumta, haliyal, ankola, mundigod, siddapur ,yellapur, uttarkannada, supa | 1437169 |
| Udupi | Udupi, kundapura, karkal, shiroor, bramhavar | 1177361 |
| Dakshina kannada | Mangalore, sulia, puttur, belthangady, bantwal | 2083627 |

**Coastal hydrogeology**

| Coastal Districts | Coastal Hydrogeology |
|---|---|
| Uttara kannada | Shallow aquifers of alluvium along the stream courses, sea coast, cereeks, weathered zones of schists, metasedimentaries, and metavolcanics occurring between the depths of 3 to 20 mbgl. Deeper aquifers of fractured and jointed schists, gneisses and metavolcanics and meta sedimentaries up to 200mbgl.<br><br>Soil types: - Hilly soil,lateriticsoil, loamy soil and semi-black cotton soil.<br>Rivers:- kali, sharavati, gangavali and aganashini. |
| Udupi | Granatic gneisses, PGC with migmatites, laterite capping, coastal alluvium, fluviatile deposits and basic and acidic intrusive.<br>Soil types:- Sandy soil, yellow loamy soil, red lateritic soil.<br>Rivers:- Netravati, kumaradhara, gurupur, nandini, shambavi. pangala, udyavar, suvarna, seethe, panchagangavalli, sowparnika, varahi, chakra. |
| Dakshinakannada | Gneiss,schist, granite and alluvium.<br>Soil types :lateritic soil<br>Rivers: Netravati, kumaradhara, gurupur, shambavi and payaswini. |

Groundwater sampling: Totally 27 groundwater samples along with 2 seawater samples are collected twice, first set of samples were collected on 20/01/2017 to 24/01/2017 and second set of samples were collected on 18/03/2017 and 19/03/2017 on the same site.

## 2.2: Objective and scopes:

The overall objective of this study is to explore the seawater intrusion in the Karnataka coastal region, in order to identify the areas of the city with the highest priority for adaptation action implementation.

The main objective of this study is to map out the coastal region affected by seawater intrusion in order to prevent groundwater pollution.

The scope of the study is to differentiate the origin of the pollution; that due to sea water intrusion from that due to any other causes. In the other words given a sample of saline water in study area, the study determines whether the cause of the salinity is indeed due to sea water intrusion.

The scope of the study does not include recommending solutions for the problem. Our study can provide input for another study, which may recommend solution.

## 2.3: Method of sampling and sampling procedure

Before testing, the water sample is collected from the sources of water. These samples should be collected from such place that they represent the body of the water from which they are collected.

Following points should be kept in view while collecting the samples

1. If the water is collected from the tap sufficient quantity of water should be allowed to pass through the tap before collecting sample from it because it will eliminate the stagnant water.
2. In case the water is being collected from the ground sources i.e., through well or tube well, sufficient quantity of water should be pumped out before collecting the samples.

**Water samples**

For physical examinations water can be collected in fully cleaned ordinary buckets or plastic jarricans. If the water is to be collected for chemical tests should be thoroughly washed cleaned and the water should be collected in it. Care was taken to see that no air entered the sampling bottle by immersing the sampling bottle inside the bucket. Gloves was used to prevent any pollution during handling.

- The Quantity of sample collected was 250ml.
- Air tight bottles are used and the sample bottles should be completely filled.
- The LAT-LONG of the sampling location is noted.

## 2.4: Field report

**Location**

Approximate grid and map plan was created and the samples were taken nearby the grid intersection points before taking the samples a call was made to Dr. Someshwar Rao, scientist E, NIH, who approved the location of sampling points.

**Sample number**: - 01

**Type of sample**: - SW

**LAT-LONG:**-12°59'18"N 74°47'35"E

**Place:**-Mangalore beach point,
Surathkal.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-01 | SGDK-01a |
| **EC** | 97000 | 101000 |
| **$\delta^{18}0$** | 0.77 | 0.96 |
| **Date** | 20thJAN 2017 | 18th march 2017 |

❖ Water sample is collected by the help of fishermen

**Sample number**: - 02

**Type of sample**: - BW

**LAT-LONG**: - 12°59'19"N 74°47'43"E

**Place:**-Near Mangalore beach point,
Surathkalguddekoppa,
iddyagrama, surathkal.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-02 | SGDK-02a |
| **EC** | 690 | 720 |
| **$\delta^{18}0$** | -1.60 | -1.57 |
| **Date** | 20th JAN 2017 | 18th MAR 2017 |

❖ This sample is bore well water sample found near beach, it is not used for drinking purpose as it is bit saline in taste, we have found this sample in residential house.

**Sample number**: - 03

**Type of sample**: - BW

**LAT-LONG**:- 12°59'23"N 74°48'6"E

**Place:** - Sri Tara tower,
near market road,
surathkal.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-03 | SGDK-03a |
| **EC** | 410 | 360 |
| **$\delta^{18}0$** | -1.96 | -1.82 |
| **Date** | 20th JAN 2017 | 18thMAR 2017 |

❖ This is the bore well water sample found in Tara wine shop and restaurant in surathkal, this sample is not used for drinking purpose as it is saline in taste, water colour changes to yellow when it is stored more than a day. Bad smell and highly saline in taste.

**Sample number**: - 04

**Type of sample**: - BW

**LAT-LONG**: - 12°59'13"N 74°48'20"E

**Place**: - Near railway bridge, Surathkal.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-04 | SGDK-04a |
| **EC** | 330 | 330 |
| **$\delta^{18}0$** | -2.06 | -2.04 |
| **Date** | 20th JAN 2017 | 18thMAR 2017 |

❖ This is the public bore well water sample found near Railway Bridge,surathkal.This water is used for drinking but it has bad smell, when it is stored for a day, oily layer is formed.

**Sample number: -** 05

**Type of sample**: - BW

**LAT-LONG**: 12°58'51"N 74°49'24°E

**Place**: - India oil petrol bunk, Bala,Surathkal.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-05 | SGDK-05a |
| **EC** | 320 | 260 |
| **δ $^{18}$0** | -2.18 | -2.06 |
| **Date** | 20th JAN 2017 | 18thMAR 2017 |

❖ This is the bore well water sample found in petrol bunk,bala,surathkal.This water is used for drinking after purifying (R.O).

**Sample number**: - 06

**Type of sample**: - BW

**LAT-LONG**: 12°58'51"N 74°49'24°E

**Place**: - Malpe beach, Malpe.
Sample test results

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-06 | SGDK-06a |
| **EC** | 60 | 60 |
| **δ $^{18}$0** | -0.63 | +0.51 |
| **Date** | 20th JAN 2017 | 18thMAR 2017 |

❖ This water sample is collected at malpebeach, this water is used for drinking.

**Sample number**: - 07

**Type of sample**: - BW

**LAT-LONG**: 13°21'42"N74°42'11"E

**Place**: - Vigneshnilaya,
nearvadamandeshwara temple,
Malpe.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-07 | SGDK-07a |
| **EC** | 560 | 460 |
| **δ $^{18}$0** | -1.94 | -2.02 |
| **Date** | 20th JAN 2017 | 18thMAR 2017 |

❖ This water sample is collected in residential house, malpe. This water is used for drinking.

**Sample number:** - 08

**Type of sample:** - BW

**LAT-LONG:**-13°21'37"N 74°42'13"E

**Place:** - Hotel malpe,
vadamandeshwara, Malpe.
Sample test results

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-08 | SGDK-08a |
| **EC** | 380 | 490 |
| **δ $^{18}$0** | -2.00 | -1.84 |
| **Date** | 21th JAN 2017 | 18thMAR 2017 |

❖ This bore well water sample is collected in hotel malpe, it is used for drinking purpose after purifying.

**Sample number**: - 09

**Type of sample**: - BW

**LAT-LONG**: 13°22'3"N 74°43'21"E

**Place**: - Dayalakshmi ice unit,
lakshminagar,
kodavru,udupi.
Sample test results

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-09 | SGDK-01a |
| **EC** | 670 | 690 |
| **δ $^{18}$0** | -1.94 | -1.89 |
| **Date** | 21th JAN 2017 | 18thMAR 2017 |

❖ This bore well is found in Dayalakshmi ice manufacturing unit, kodavoor. This bore well is not used in industry for ice manufacturing as it ishighly saline in nature.

**Sample number: - 10**

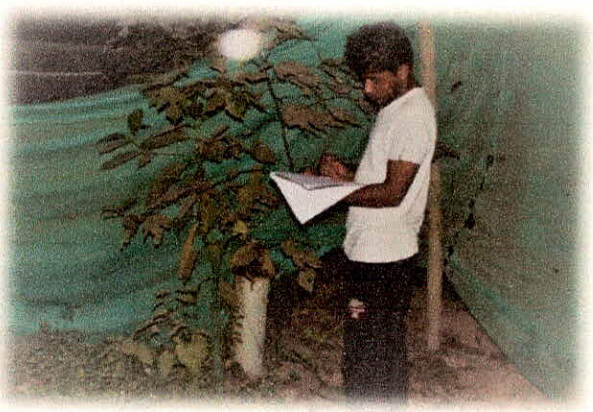
**Type of sample: -** BW

**LAT-LONG: -**13°23'5"N 74°44'13"E

**Place: -**Nayampally apartment,
Near suraj book stores,
kalyampura, santhekatte.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-10 | SGDK-10a |
| **EC** | 200 | 160 |
| **δ $^{18}$0** | -1.93 | -1.94 |
| **Date** | 21th JAN 2017 | 18thMAR 2017 |



❖ This bore well is found in apartment near suraj book stores,santekatte, nayampally.This water is used for drinking purpose.

**Sample number**: - 11

**Type of sample**: - BW

**LAT-LONG**: 13°22′29″N 74°44′37″E

**Place:** - Lakshmi Venkateshwara temple, santekatte,puttur village, Udupi. Sample test results

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-011 | SGDK-11a |
| **EC** | 340 | 310 |
| **δ $^{18}$0** | -2.26 | -1.95 |
| **Date** | 21th JAN 2017 | 18thMAR 2017 |

❖ This borewell is found in Lakshmi Venkateshwara temple, santekatte, puttur village, Udupi. Water is not used for drinking purpose.

**Sample number: - 12**

**Type of sample: -** BW

**LAT-LONG:** -13°33'44"N 74°40'49"E

**Place: -** Near koravadi beach, Gopadi, kundapura, Udupi.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-12 | SGDK-12a |
| **EC** | 550 | 490 |
| **δ $^{18}$0** | -1.59 | -1.39 |
| **Date** | 22th JAN 2017 | 18thMAR 2017 |

❖ This bore well is found near koravadi beach, it is found in residential house, the water is used for drinking and farming purposes. Water is not saline but yellow in colour.

**Sample number**: - 13

**Type of sample:** - BW

**LAT-LONG:** - 13°33'47"N 74°40'54"E

**Place:** -Gopadi, kundapura, Udupi.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-13 | SGDK-13a |
| **EC** | 440 | 440 |
| **$\delta^{18}0$** | -0.48 | -0.85 |
| **Date** | 21th JAN 2017 | 18thMAR 2017 |

❖ This is the bore well water sample collected in residential house, the water is clear and used for drinking purpose.

**Sample number**: -14

**Type of sample:** - BW

**LAT-LONG:** -13°33'36"N 74°41'10"E

**Place:** - Asha goyadi mane, Koravadi, Kundapura, Udupi.

Sample test results

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-14 | SGDK-14a |
| **EC** | 200 | 240 |
| **$\delta^{18}0$** | -1.98 | -2.21 |
| **Date** | 22th JAN 2017 | 18thMAR 2017 |

❖ This is bore well water sample found in residential house, water is yellow in colour and it is not used for drinking purpose but it is used for farming.

**Sample number: - 15**

**Type of sample: -** BW

**LAT-LONG: -** 13°33'41"N 74°41'17"E

**Place: -**Sri Padma nilaya,
Near health centre,
Koravadi, Kundapura, Udupi.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-15 | SGDK-15a |
| **EC** | 100 | 110 |
| **$\delta^{18}0$** | -1.15 | -1.15 |
| **Date** | 22th JAN 2017 | 18thMAR 2017 |

❖ This borewell water sample is found in residential house, koravadi. The water is used for drinking.

**Sample number: -16**

**Type of sample: -** BW

**LAT-LONG: -** 13°34'9"N 74°41'55"E

Place: - At auto stand, Kumbashi,
Kundapura, Udupi.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-16 | SGDK-16a |
| **EC** | 260 | 250 |
| **$\delta^{18}0$** | -1.98 | -2.09 |
| **Date** | 22th JAN 2017 | 18thMAR 2017 |

❖ This bore well is found at auto stand, kumbashi. The water from the bore well is not used for drinking purpose.

**Sample number:** - 17

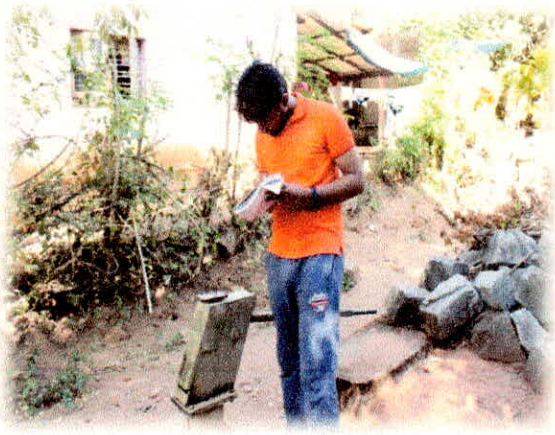
Type of sample: - BW

**LAT-LONG:** - 13°34'17"N 74°42'6"E

**Place:** -Vinayakanagar,
Near aneguddaganapathi temple,
Kumbashi, Kundapura, Udupi.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-17 | SGDK-17a |
| **EC** | 100 | 100 |
| **$\delta^{18}0$** | -1.90 | -1.95 |
| **Date** | 22th JAN 2017 | 18thMAR 2017 |



❖ It is a public bore well, water is impure and highly muddy in nature, the people over there are facing a major water scarcity problem for their daily needs.

**Sample number**: -18

**Type of sample:** - BW

**LAT-LONG:** -13°34'12"N 74°42'20"E

**Place:** -Anegudde, Kumbashi,
Kundapura, udupi.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-18 | SGDK-18a |
| **EC** | 110 | 130 |
| **$\delta^{18}0$** | -2.12 | -2.00 |
| **Date** | 22th JAN 2017 | 18thMAR 2017 |

❖ The bore well is found at residential house, the water is not used for drinking purpose.

**Sample number**: - 19

**Type of sample:** - BW

**LAT-LONG:** - 13°34'13"N 74'42'53"E

**Place:** -Horkwady village, Kundapura, Udupi.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-19 | SGDK-19a |
| **EC** | 140 | 190 |
| **$\delta^{18}0$** | -1.81 | -2.16 |
| **Date** | 23th JAN 2017 | 18thMAR 2017 |

❖ It is a public bore well. Water from this bore well is not used for drinking purposes.

**Sample number**: -20

**Type of sample:** - BW

**LAT-LONG:** -13°52'28"N 74°36'11"E

Place: - Near Ayappaswamy temple, BydoorDombe, Byndoor

**.Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-20 | SGDK-20a |
| **EC** | 50 | 60 |
| **$\delta^{18}0$** | -1.88 | -1.59 |
| **Date** | 23th JAN 2017 | 18thMAR 2017 |

❖ Water from this bore well is not used for drinking purpose but it is used for farming.

**Sample number: -** 21

**Type of sample: -** BW

**LAT-LONG: -**13°52'32"N 74°37'45"E

**Place: -**Near Rattubhai school, Hemmady, Kundapura, Udupi.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-21 | SGDK-21a |
| **EC** | 630 | 610 |
| **$\delta^{18}0$** | -1.90 | -1.70 |
| **Date** | 23th JAN 2017 | 18thMAR 2017 |

**Sample number**: -22

**Type of sample: -** BW

**LAT-LONG: -**13°52'24"N 74°37'44"E

**Place: -**Mayur petrol bunk, Byndoor.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-22 | SGDK-22a |
| **EC** | 440 | 440 |
| **$\delta^{18}0$** | -2.09 | -1.93 |
| **Date** | 23th JAN 2017 | 18thMAR 2017 |

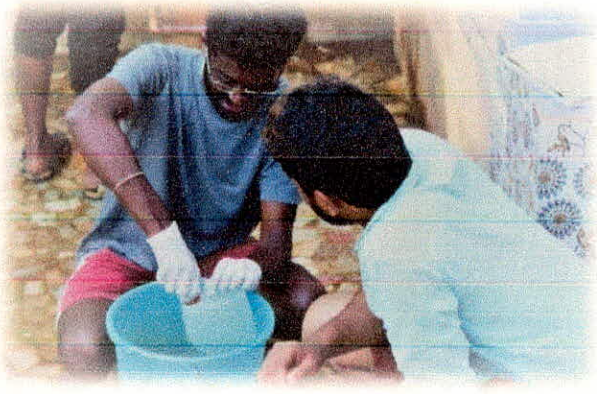
❖ The bore well is found at mayur petrol bunk,byndoor.The water is used for drinking after filtering.

**Sample number**: - 23

**Type of sample: -** BW

**LAT-LONG:** -14°0'39"N 74°30'39"E

**Place: -**Government primary school, Hartar, Bhatkal.



**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-23 | SGDK-23a |
| **EC** | 200 | 180 |
| **$\delta^{18}0$** | -2.15 | -1.88 |
| **Date** | 23th JAN 2017 | 18thMAR 2017 |

❖ Bore well is located at government primary school.The water is used for gardening and not for drinking purpose.

**Sample number**: -24

**Type of sample: -** BW

**LAT-LONG:** -14°0'45"N 74°31'6"E

**Place: -** Luggage auto rickshaw stand, Bhatkal.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-24 | SGDK-24a |
| **EC** | 190 | 210 |
| **$\delta^{18}0$** | -2.42 | -2.14 |
| **Date** | 23th JAN 2017 | 18thMAR 2017 |

❖ This public bore well is found near luggage auto stand,bhatkal.The water colour was yellow and it is not used for drinking purpose.

**Sample number: -** 25

**Type of sample: -** BW

**LAT-LONG: -**14°0′26″N 74°31′55″E

**Place: -**In front of kadhimachine, Rehmadabad, Bhatkal.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-25 | SGDK-25a |
| **EC** | 160 | 80 |
| **$\delta^{18}0$** | -1.57 | -1.91 |
| **Date** | 23th JAN 2017 | 18thMAR 2017 |

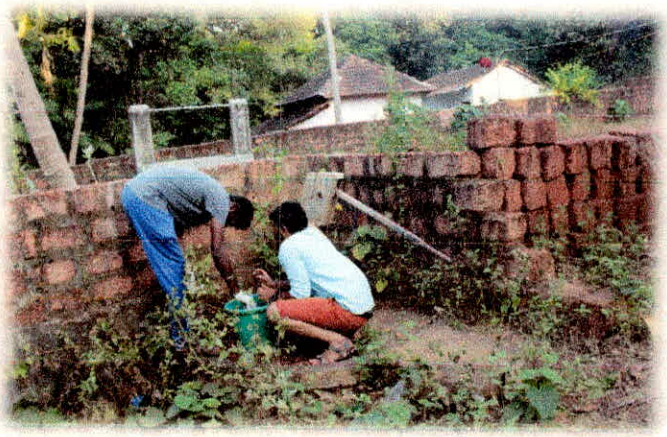
This public bore well is found in front of kadhimachine, rehmadabad ,bhatkal. The water is not used for drinking purposes,oily layer and oily smell is noticed.

**Sample number: -**26

**Type of sample: -** BW

**LAT-LONG: -**14°0′8″N 74°33′12″E

**Place: -** Near police ground, Bhatkal.



**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-26 | SGDK-26a |
| **EC** | 210 | 210 |
| **$\delta^{18}0$** | -2.0 | -1.92 |
| **Date** | 23th JAN 2017 | 18thMAR 2017 |

❖ This bore well is found near police ground, Bhatkal.The water is not used for drinking purpose.

**Sample number: -** 27

**Type of sample: -** SW

**LAT-LONG: -**14°0′34″N 74°30′28″E

**Place: -**Bhatkal beach.

**Sample test results**

| | 1st set | 2nd set |
|---|---|---|
| **Site ID** | SGDK-27 | SGDK-27a |
| **EC** | 92000 | 107000 |
| **$\delta^{18}0$** | +0.87 | +0.93 |
| **Date** | 23th JAN 2017 | 18thMAR 2017 |

❖ It is the sea water sample collected in bhatkal beach by the help of fishermen. Sample water is collected about 1km away from the beach (inside the sea).

# Chapter-3

# METHODOLOGY

# CHAPTER 3

# METHODOLOGY

## 3.1:- Measurement of electrical conductivity

Electrical conductivity is very quick, simple and inexpensive method used to find out the conductivity of the sample. Since the electrical conductivity is the measure to the capacity of water to conduct electrical current, it is directly related to the concentration of salts dissolved in water, and therefore to the total dissolved solids (TDS). Salts dissolved into positively charged ions, which conduct electricity.

Since it is difficult to measure TDS in the field, the electrical conductivity of the water is used as measure. The electrical conductivity of the water can be determined in a quick and inexpensive way, using portable meters.

Distilled water does not contain dissolved salts, as result it does not conduct electricity and has an electrical conductivity of zero.

Nevertheless, when the salt concentration reaches a certain level, electrical conductivity is no longer is directly related to salt concentration. This is because ion pairs are formed. Ion pairs weaken each other's charge, so that above this level, higher TDS will not result in equally higher electrical conductivity.

Unit: micro Siemen's/cm

Equipment:

Distilled water

Water sample

Procedure followed:

- Immune probers into water sample (2cm is sufficient) dire to clear any trapped air bubbles.
- The upper display shows the conductivity of the solution. Automatically temperature is compensated to 25°c.

- The lower display shows the temperature of the solution.
- Note the units on the screen$\mu s/cm$.
- Read and record the EC reading if units are in$\mu s/cm$.
- Record EC value in result sheet.

**Check list:**

- Seawater has approximately 50,000 EC'S.
- Salt taste in water has 1,500 to 2000 EC'S.
- Fresh glacier water has EC below 100.
- The EC value of distilled water is Zero

## 3.2: Isotope analysis

**Mass spectrometry:**

Mass spectrometry has been described as the smallest scale in the world, not because of its size but because of the size of the thinks it weighs. Mass spectrometry, also called mass spectroscopy, is an instrumental approach that allows for the mass measurement of molecules.

The five basic parts of any mass spectrometer are: a) a vacuum system; b) a sample introduction device; c) an ionization source; d) a mass analyzer; and e) an ion detector. Combining these parts a mass spectrometer determines the molecular weight of chemical compound by ionizing, separating and measuring molecular ions according to their mass-to-charge ratio (m/z). The ions are generated in the ionization source by inducing either the loss or the gain of a charge (e.g. electron ejection, protonation, or deprotonating). Once the ions are formed in the gas phase they can be electrostatically directed into a mass analyzer, separated according to the mass and finally detected. The result of ionization, ion separation, and detection is a mass spectrum.

In order to measure the characteristics of individual molecules, a mass spectrometer converts them to ions so that they can be removed about and manipulated by

external electric and magnetic fields. Because ions are very reactive and short lived, their formation and manipulation must be conducted in a vacuum. Atmospheric pressure is about 760 torr (mm of mercury). The pressure under which ions may be handled is roughly $10^{-5}$ to $10^{-8}$ torr (less than billionth of an atmosphere). Each of the three tasks listed above may be accomplished in different ways. In one common procedure, ionization is effected by a high energy beam of electrons, and ion separation is achieved by accelerating and focusing the ions in a beam. Which is then bent by an external magnetic field? The ions are then detected electronically and the resulting information is stored and analyzed in a computer. A mass spectrometer operating in this fashion is outlined in the following diagram. The heart of the spectrometer is the ion source. Here molecules of the sample (black dots) are bombarded by electrons (light blue lines) issuing from a heated filament. This is called an EI (electron-impact) source. Gases and volatile liquid samples are allowed to leak into the ion source from a reservoir (as shown), but non-volatile solids and liquids may be introduced directly. Cations formed by the electrons bombardment (red dots) are pushed away by a charged repellor plate (an ions are attached to it), and accelerated toward other electrodes, having slits through which the ions pass as a beam. Some of these ions fragment into smaller cat ions and neutral fragments. When the ion beam experiences a strong magnetic field perpendicular to its direction of motion, the ions are deflected in an arc whose radius is inversely proportional to the mass of the ion. Lighter ions are deflected more than heavier ions. By varying the strength of magnetic field, ions of different mass can be focused progressively on a detector fixed at the end of a curved tube (also under a high vacuum).

When a high energy electron colloids with a molecule it often ionizes it by knocking away one of the molecular electrons (either bonding or non-bonding). This leaves behind a molecular ion. Residual energy from the collision may cause the molecular ion to fragment into neutral pieces and smaller fragment ions. The molecular ions are a radical cat ion, but the fragment ions may either be radical cat ion or carbon-cat ions, depending on the nature of the neutral fragment.

**The nature of the mass spectra:**

The mass spectrum will usually be presented as a vertical bar graph, in which each bar represents an ion having a specific mass-to-charge ratio (m/z) and length of the bar indicate the relative abundance of the ion. The most intense ion is assigned an abundance of 100, and it is refer to as the base peak. Most of the ions formed in a mass spectrometer have a single charge, so the m/z value is equivalent to mass itself.

Modern mass spectrometers easily distinguish (resolve) ions differing by only a single atomic mass unit (amu), and thus provide completely accurate values for the molecular mass of a compound. The highest-mass ion in a spectrum is normally considered to be the molecular ion, and lower-mass ions are fragments from the molecular ion, assuming the sample is a single pure compound.

**Dual-inlet gas source mass spectrometry:**

In 1947, AlfiedNier developed the first dual-inlet, double-collector gas source mass spectrometer. The double-collector allowed the simultaneous measurement of the isotopes and the dual-inlet allowed ratio measurement on both a sample and a standard by alternating between inlets. Gas source mass spectrometry has since become the measurement technique of preference for isotope ratios of most of the lighter elements (e.g. H, C, N, O and S) because if it's relative simplicity and because the use of intermediate standards allows comparison of data bases from different laboratories. A base of preparation methods have been developed and improved to convert different sample compounds to an appropriate gas including $CO_2$, $SO_2$, $H_2$ and$N_2$.

A heated tungsten-coated iridium (thoria) filament inside the source block cavity ionizes a laminar steam of gas entering the ultra-high vacuum source. The gas molecules are stripped of one electron, producing positive ions (e.g. $CO_2^+$) which are then accelerated through a voltage gradient and focused into the flight tube upon existing the source. The ionization efficiency varies between 0.01 and 0.1% for different instrument. The ion beam bends as it passes through the field of a magnet installed over the flight tube. Here, the beam separates into a spectrum of masses according to the isotopes present.

Each mass beam continues to the ion detectors where preset faraday cup collectors measures each ion current. By collecting two or three ion beams simultaneously, the ion currents can be expressed as a mass ratio. For example, $CO_2$ would contribute three principle peaks at mass 44 ($^{12}C^{18}O_2$), mass 45 ($^{13}C^{18}O_2$ or $^{12}C^{17}O^{16}O$) and mass 46 ($^{12}C^{18}O^{19}O$). A dual-inlet system allows the mass spectrometer to alternatively measure ratio in the sample and a working or laboratory standard. Thus, the extreme fractionation impacted from drifting electronics, which precluded accurate abundance measurements. These instabilities have since been overcome with solid-state and fiber optic signal transfer systems.

Fig.3.2.1 schematic of the gas source isotope ratio mass spectrometer (IRMS), showing both continues flow and dual inlets. A continues flow inlet here is shown with a sample combustion and gas chromatograph configuration. Capillary tubes ensure laminar, non-fractionating gas flow. Example shows mass range of $CO_2$ gas, and includes the short rådius flight tube for $H_2$ found a many designs. Other mass ranges (for $SO_2$ and $N_2$) are attained by either additional fixed-position faraday collectors or by adjusting the beam.

Quadruple mass spectrometers employ a method of isotope separation and measurement that offers economics in a size and cost, but lack the precision of a Nier-type instrument. However, the portability of quadruple mass spectrometry allowed the Viking mission to perform isotope analysis of Martian soil and atmosphere.

The direction of gas source mass spectrometry is now towards continuous flow systems where the sample and standard gases are carried into the mass spectrometer source in a stream of helium gas. In this way, pulse injections of sample gas can be analyzed, reducing volume constrains and sample size. Measurement is the mass mole ($10^{-9}$ moles of gas) size range is now possible, opening a host of research possibilities. These systems also greatly increase sample through-put when configurated with automated sample preparation systems. In particular, an element analyzer on the front end of continues flow mass spectrometer allows the analysis of solid, liquid, and mixed matrix samples which can be combusted and the gases separate on a chromatographic column. Helium carries the sample through the column and into the mass spectrometer.

Continuous flow mass spectrometers configured with a laser ablation sampling system provide researches with a tool for micro-analysis of sulphides and carbonates, with a spatial resolution in the order of 10 to 50m.

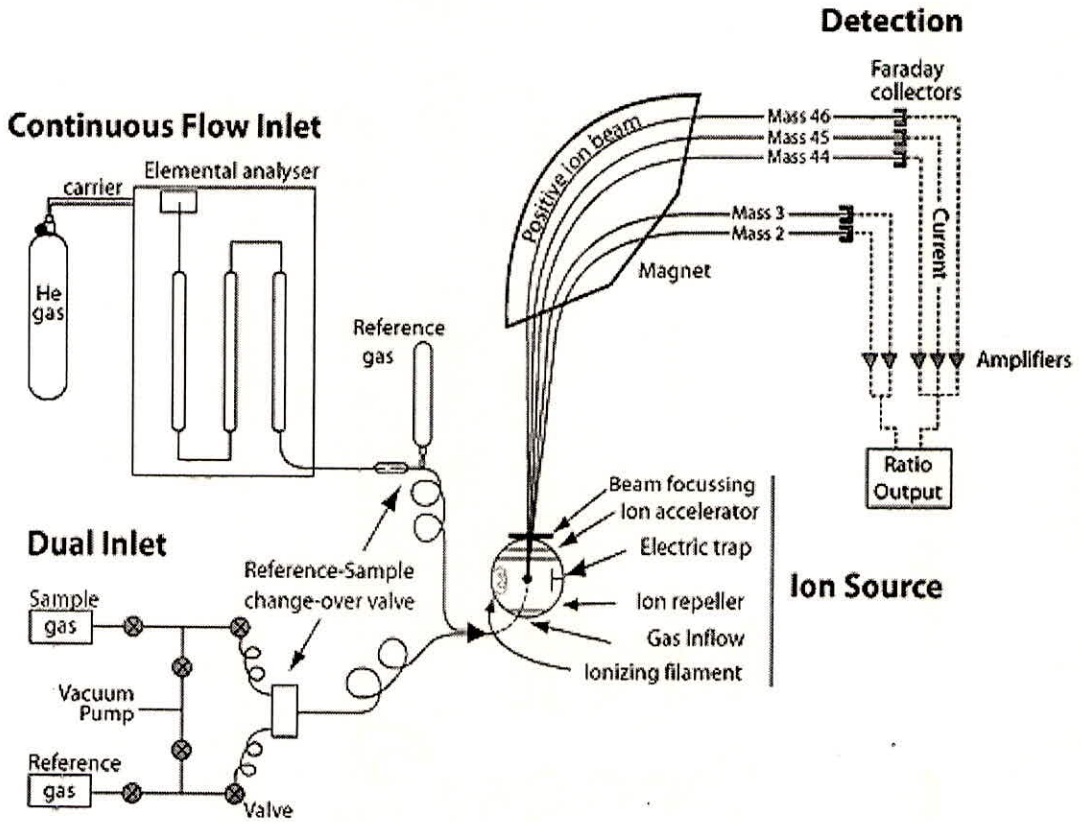



**Fig.3.2.1 Schematic of the gas source isotope ratio mass spectrometer.**

**Measurement procedure:**

At first samples are arranged simultaneously preferably date wise on a tray. Then entries are made in a registrar giving out the following details

| serial No, (vile No) | Date | Sample No | Location | $^{18}O$ | Remark |
|---|---|---|---|---|---|
| | | | | | |

Then uncontaminated dry vials (sample tubes) are kept ready. With the help of a transferrpotte-400 µl of water sample is taken in each vile. Before taking the sample it

should evaporation . There should not be any contamination while pouring the sample in the vile. Again it should be ensured that the same volume of sample is taken in each vile. Otherwise errors will be high. After each sampling in the vials it is to be checked that the vile number and serial number in the registrar are same. After pouring the samples the vials should be tightly capped.

The samples are then mounted in the sample cabin of the dual-inlet Aqun-prep mass spectrometer. The temperature in the sample cabin is maintained at 40°C throughout the experiment. The analyses run for approximately 22 hours for oxygen. High vacuum is created within the valves in the spectrometer. The samples are taken from the vials by automatic sampler. For oxygen analysis $CO_2$is equilibrated with oxygen vapors which are made to release from liquid samples.

At first $CO_2$ is equilibrated with the sample water or standard (VSMOW, SLAP). Measurements are made on the oxygen compound of the $CO_2$.

$$\delta^{18}_{sample/standard} = ({}^{18}R_{sample} / {}^{18}R_3) - 1$$

$$= ({}^{18}R_{\text{co2 is equalization with water}} / {}^{18}R_{\text{co2 is equalization with VSMOW}})$$

**Standards:**

$${}^{18}R_{\text{VSMOW- water}} < 20005.2*10^{-6}$$

$${}^{18}R_{\text{SLAP - water}} < 1893.9104*10^{-6}$$

As the samples are mounted, software names "MASSLYNX 4.0 I" developed by GV instruments, U.K helps to run the instruments and analysis the samples. The data that is obtained after the experiments is raw in form. It is processed to get rid of instrumental and other errors and is calibrated with respect to standards. Ultimately what we get are certain numbers with respect to standards. In case of oxygen the standards are VSMOW and SLAP. The oxygen isotopic data that is obtained after the analysis is given in table.

# Chapter-4

# ANALYSIS AND RESULTS

# CHAPTER-4

# ANALYSIS AND RESULTS

## 4.1: Results

**Measured parameters, value range and location name:**

| Parameters | Minimum & Maximum concentration & the Observed place | | | | | |
|---|---|---|---|---|---|---|
| | 1st set(JAN) | | | 2nd set(MARCH) | | |
| | Minimum | Maximum | Average | Minimum | Maximum | Average |
| EC (μS/cm) | 50 | 690 | 370 | 60 | 720 | 390 |
| $\delta^{18}O$ | -2.42 | -0.48 | -1.45 | -2.21 | 0.51 | -0.85 |

**Results Tabulations of 1st Set Samples**

| Site ID | Location | Date | lat | | long | | Source | EC | δO18 |
|---|---|---|---|---|---|---|---|---|---|
| SGDK-1 | Mangalore beach,Suratkal | 1/20/2017 | 12°59'18" | 12.98833 | 74°47'35" | 74.79306 | SW | 97000 | 0.77 |
| SGDK-2 | Suratkal Beach | 1/20/2017 | 12°59'19" | 12.98861 | 74°47'43" | 74.79528 | BW | 690 | -1.60 |
| SGDK-3 | Kana near B.C , kaikamba road | 1/20/2017 | 12°59'23" | 12.98972 | 74°48'6" | 74.80167 | BW | 410 | -1.96 |
| SGDK-4 | Suruthkal near kadambody road at the depth of 400ft | 1/20/2017 | 12°59'13" | 12.98694 | 74°48'20" | 74.80556 | BW | 330 | -2.06 |
| SGDK-5 | Hosabettu | 1/20/2017 | 12°58'51" | 12.98083 | 74°49'24" | 74.82333 | BW | 320 | -2.18 |
| SGDK-6 | Malpe beach near malpe light house | 1/21/2017 | 13°21'41" | 13.36139 | 74°41'54" | 74.69833 | BW | 60 | -0.63 |
| SGDK-7 | Malpe | 1/21/2017 | 13°21'42" | 13.36167 | 74°42'11" | 74.70306 | BW | 560 | -1.94 |
| SGDK-8 | Near Udupi-malpe highway | 1/21/2017 | 13°21'37" | 13.36028 | 74°42'13" | 74.70361 | BW | 380 | -2.00 |
| SGDK-9 | Malpe road,Tenkanidyoor | 1/21/2017 | 13°22'3" | 13.3675 | 74°43'21" | 74.7225 | BW | 670 | -1.94 |
| SGDK-10 | Kallianpur main road | 1/21/2017 | 13°23'5" | 13.38472 | 74°44'13" | 74.73694 | BW | 200 | -1.93 |
| SGDK-11 | Arithodu Temple road,Subhrahmanyanagar | 1/21/2017 | 13°22'29" | 13.37472 | 74°44'37" | 74.74361 | BW | 340 | -2.26 |
| SGDK-12 | Gopadi at the depth of 20ft | 1/22/2017 | 13°33'44" | 13.56222 | 74°40'49" | 74.68028 | BW | 550 | -1.59 |
| SGDK-13 | Kome | 1/22/2017 | 13°33'47" | 13.56306 | 74°40'54" | 74.68167 | BW | 440 | -0.48 |
| SGDK-14 | Gopadi | 1/22/2017 | 13°33'36" | 13.56 | 74°41'10" | 74.68611 | BW | 200 | -1.98 |
| SGDK-15 | Gopadi at the depth of 25ft | 1/22/2017 | 13°33'41" | 13.56139 | 74°41'17" | 74.68806 | BW | 100 | -1.15 |
| SGDK-16 | Arasarabettu at the depth of 70ft | 1/22/2017 | 13°34'9" | 13.56917 | 74°41'55" | 74.69861 | BW | 260 | -1.98 |
| SGDK-17 | Vokwadi road,kumbashi at the depth of 300ft | 1/22/2017 | 13°34'17" | 13.57139 | 74°42'6" | 74.70167 | BW | 100 | -1.90 |
| SGDK-18 | Anegudde Vinayaka temple road,Kumbashi at the depth of 780ft | 1/22/2017 | 13°34'12" | 13.57 | 74°42'20" | 74.70556 | BW | 110 | -2.12 |
| SGDK-19 | vokwadi road,kumbashi | 1/23/2017 | 13°34'13" | 13.57028 | 74°42'53" | 74.71472 | BW | 140 | -1.81 |
| SGDK-20 | Byndoor Beach | 1/23/2017 | 13°52'28" | 13.87444 | 74°36'11" | 74.60306 | BW | 50 | -1.88 |
| SGDK-21 | Edapally-Panvel highway,Paduvari | 1/23/2017 | 13°52'32" | 13.87556 | 74°37'45" | 74.62917 | BW | 630 | -1.90 |
| SGDK-22 | Prashanth,Someshwar road,Byndoor,paduvari at depth of 140ft | 1/23/2017 | 13°52'24" | 13.87333 | 74°37'44" | 74.62889 | BW | 440 | -2.09 |
| SGDK-23 | Honnegadde at the depth of 50ft | 1/24/2017 | 14°0'39" | 14.01083 | 74°30'39" | 74.51083 | HP | 200 | -2.15 |
| SGDK-24 | Kattinakaru near turthalli fall | 1/24/2017 | 14°0'45" | 14.0125 | 74°31'6" | 74.685 | PHP | 190 | -2.42 |
| SGDK-25 | Bendekant | 1/24/2017 | 14°0'26" | 14.00722 | 74°31'55" | 74.53194 | PHP | 160 | -1.57 |
| SGDK-26 | Kargedde | 1/24/2017 | 14°0'8" | 14.00222 | 74°33'12" | 74.55333 | PHP | 210 | -2.00 |
| SGDK-27 | Honnegadde | 1/24/2017 | 14°0'34" | 14.00944 | 74°30'28" | 74.50778 | SW | 92000 | 0.87 |

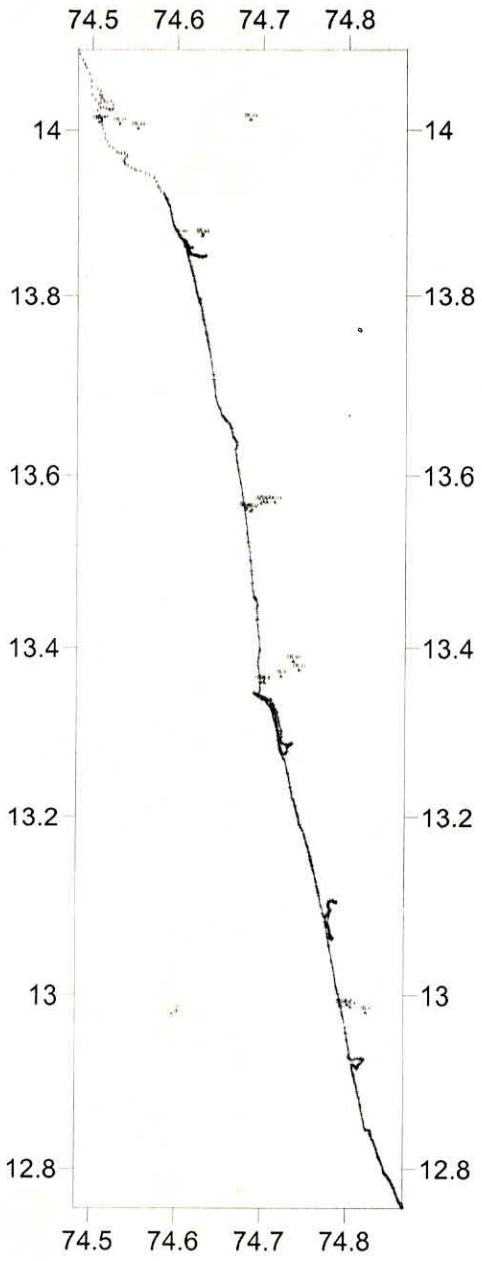
HP –Hand pump
BW- Bore well
PHP- Public Hand Pump
SW-SEA Water

**Results Tabulations of 2nd Set Samples**

| Site ID | Location | Date | lat | y | long | x | Source | EC | δO18 |
|---|---|---|---|---|---|---|---|---|---|
| SGDK-1a | Mangalore beach, Suratkal | 3/18/2017 | 12°59'18" | 12.98833 | 74°47'35" | 74.79306 | SW | 101000 | 0.96 |
| SGDK-2a | Suratkal Beach | 3/18/2017 | 12°59'19" | 12.98861 | 74°47'43" | 74.79528 | BW | 720 | -1.57 |
| SGDK-3a | Kana near B.C , kaikamba road | 3/18/2017 | 12°59'23" | 12.98972 | 74°48'6" | 74.80167 | BW | 360 | -1.82 |
| SGDK-4a | Suruthkal near kadambody road at the depth of 400ft | 3/18/2017 | 12°59'13" | 12.98694 | 74°48'20" | 74.80556 | BW | 330 | -2.04 |
| SGDK-5a | Hosabettu | 3/18/2017 | 12°58'51" | 12.98083 | 74°49'24" | 74.82333 | BW | 260 | -2.06 |
| SGDK-6a | Malpe beach near malpe light house | 3/18/2017 | 13°21'41" | 13.36139 | 74°41'54" | 74.69833 | BW | 60 | 0.51 |
| SGDK-7a | Malpe | 3/18/2017 | 13°21'42" | 13.36167 | 74°42'11" | 74.70306 | BW | 460 | -2.02 |
| SGDK-8a | Near Udupi-malpe highway | 3/18/2017 | 13°21'37" | 13.36028 | 74°42'13" | 74.70361 | BW | 490 | -1.84 |
| SGDK-9a | Malpe road, Tenkanidyoor | 3/18/2017 | 13°22'3" | 13.3675 | 74°43'21" | 74.7225 | BW | 690 | -1.89 |
| SGDK-10a | Kallianpur main road | 3/18/2017 | 13°23'5" | 13.38472 | 74°44'13" | 74.73694 | BW | 160 | -1.94 |
| SGDK-11a | Arithodu Temple road,Subhrahmanyanagar | 3/18/2017 | 13°22'29" | 13.37472 | 74°44'37" | 74.74361 | BW | 310 | -1.95 |
| SGDK-12a | Gopadi at the depth of 20ft | 3/18/2017 | 13°33'44" | 13.56222 | 74°40'49" | 74.68028 | BW | 490 | -1.39 |
| SGDK-13a | Kome | 3/18/2017 | 13°33'47" | 13.56306 | 74°40'54" | 74.68167 | BW | 440 | -0.85 |
| SGDK-14a | Gopadi | 3/18/2017 | 13°33'36" | 13.56 | 74°41'10" | 74.68611 | BW | 240 | -2.21 |
| SGDK-15a | Gopadi at the depth of 25ft | 3/18/2017 | 13°33'41" | 13.56139 | 74°41'17" | 74.68806 | BW | 110 | -1.15 |
| SGDK-16a | Arasarabettu at the depth of 70ft | 3/18/2017 | 13°34'9" | 13.56917 | 74°41'55" | 74.69861 | BW | 250 | -2.09 |
| SGDK-17a | Vokwadi road,kumbashi at the depth of 300ft | 3/18/2017 | 13°34'17" | 13.57139 | 74°42'6" | 74.70167 | BW | 100 | -1.95 |
| SGDK-18a | Anegudde Vinayaka temple road,Kumbashi at the depth of 780ft | 3/18/2017 | 13°34'12" | 13.57 | 74°42'20" | 74.70556 | BW | 130 | -2.00 |
| SGDK-19a | vokwadi road, kumbashi | 3/19/2017 | 13°34'13" | 13.57028 | 74°42'53" | 74.71472 | BW | 190 | -2.16 |
| SGDK-20a | Byndoor Beach . | 3/19/2017 | 13°52'28" | 13.87444 | 74°36'11" | 74.60306 | BW | 60 | -1.59 |
| SGDK-21a | Edapally-Panvel highway, Paduvari | 3/19/2017 | 13°52'32" | 13.87556 | 74°37'45" | 74.62917 | BW | 610 | -1.70 |
| SGDK-22a | Prashanth,Someshwar road, Byndoor, paduvari at depth of 140ft | 3/19/2017 | 13°52'24" | 13.87333 | 74°37'44" | 74.62889 | BW | 440 | -1.93 |
| SGDK-23a | Honnegadde at the depth of 50ft | 3/19/2017 | 14°0'39" | 14.01083 | 74°30'39" | 74.51083 | HP | 180 | -1.88 |
| SGDK-24a | Kattinakaru near turthalli fall | 3/19/2017 | 14°0'45" | 14.0125 | 74°31'6" | 74.685 | PHP | 210 | -2.14 |
| SGDK-25a | Bendekant | 3/19/2017 | 14°0'26" | 14.00722 | 74°31'55" | 74.53194 | PHP | 80 | -1.91 |
| SGDK-26a | Kargedde | 3/19/2017 | 14°0'8" | 14.00222 | 74°33'12" | 74.55333 | PHP | 210 | -1.92 |
| SGDK-27a | Honnegadde | 3/19/2017 | 14°0'34" | 14.00944 | 74°30'28" | 74.50778 | SW | 107000 | 0.93 |

## 4.2 : Plots

### Site ID

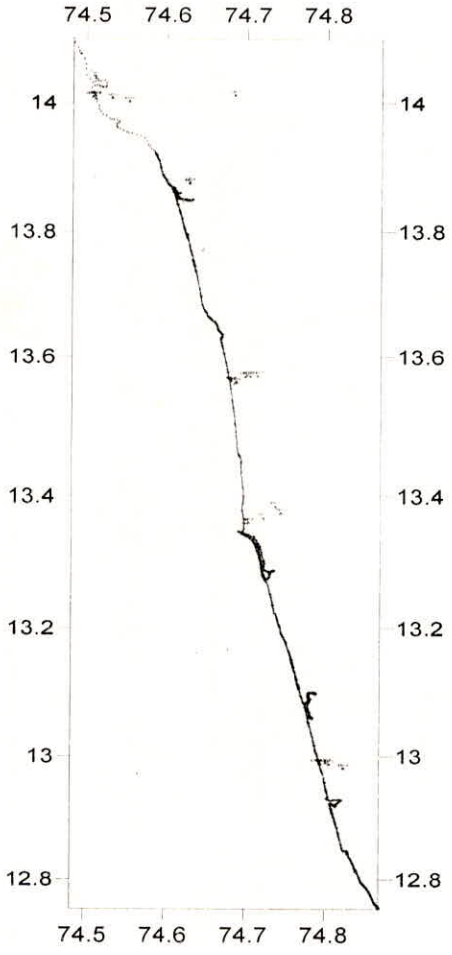



Surfer maping of site ID

**EC values of 1st set (JAN)**

| EC values of 1st set | No. of samples |
|---|---|
| <250 | 12 |
| 250-750 | 13 |
| 750-2250 | 0 |
| 2250-4000 | 0 |
| >4000 | 02 |

Table 4.2.1 EC values of 1st set

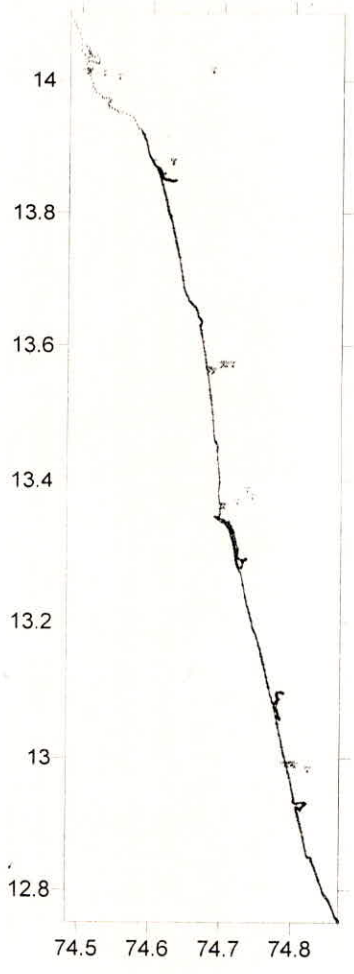



Surfer Maping of EC Values of 1st Set

**EC values of 2nd set(March)**

| EC values of 2st set | No. of samples |
|---|---|
| <250 | 13 |
| 250-750 | 12 |
| 750-2250 | 0 |
| 2250-4000 | 0 |
| >4000 | 02 |

Table 4.2.2 EC values of 2st set

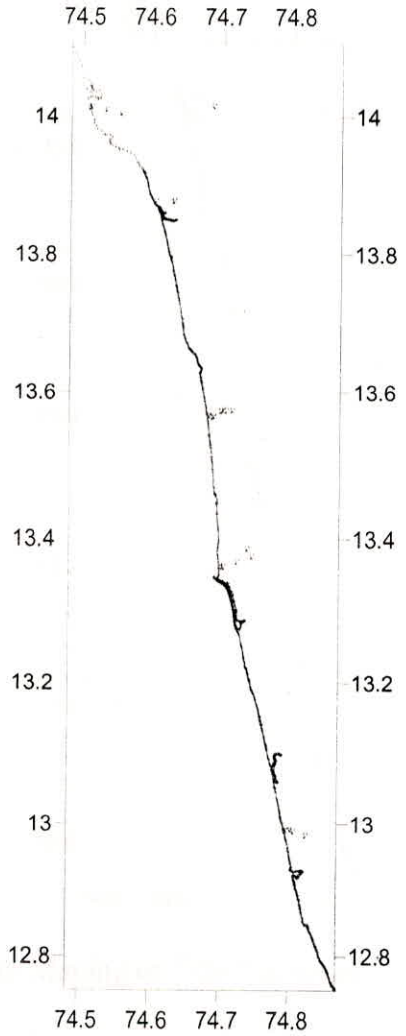



Surfer Maping of EC Values of 2nd Set

**$^{18}O\delta$ value of 1st (JAN)**

| $^{18}O\delta$ Value of 1st set | No. of points |
|---|---|
| [0 to -2] | 18 |
| [-2 to -4] | 7 |
| [less than-4] | 2 |

Table 4.2.3 Surfer Maping of EC Values of 1st Set Value of 1st set

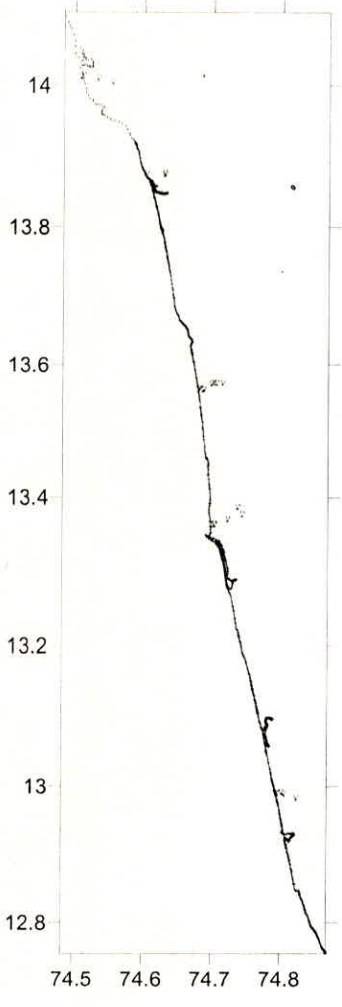



Surfer Maping of $^{18}O\delta$ Values of 1st Set

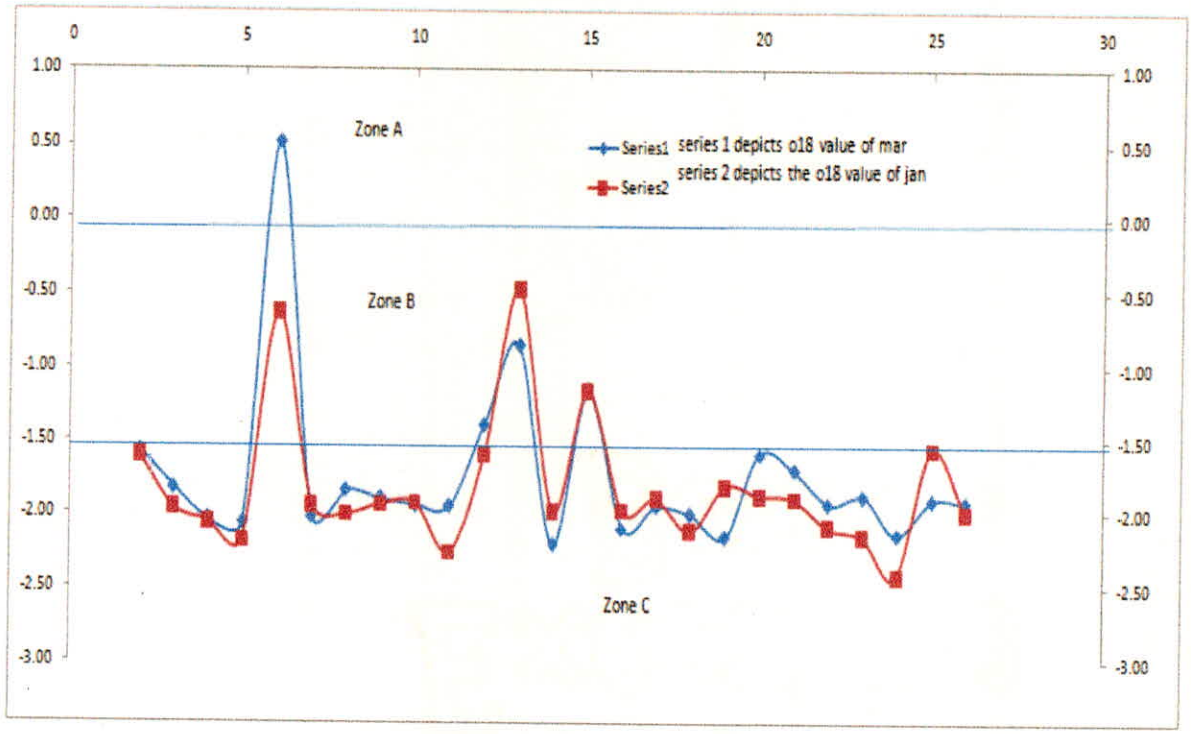
**$^{18}O\delta$ values of 2nd set**

| $^{18}O\delta$ Value of 2nd set | No. of points |
|---|---|
| [0 to -2] | 17 |
| [-2 to -4] | 7 |
| [less than -4] | 0 |

Table 4.2.4 $^{18}O\delta$ Value of 2nd set




Surfer Maping of $^{18}O\delta$ Values of 2nd Set




$^{18}O\delta$ plots of two sets of samples

ZONE C:-Areas having $^{18}O\delta$ value less than -2 can be considered to be fresh.

ZONE B:-Areas having $^{18}O\delta$ value between-1.50 to -0.50 can moderately be affected by salinity.

(PEAK 2 & 3 POINT 13 AND 15:- $^{18}O\delta$ VALUE:--0.48 AND -1.15(RED POINT ABOVE) SHOWS MODERATE SALINITY)

ZONE A:-Areas having $^{18}O\delta$ value more than -0.50 shows clear sign of salinity.

(PEAK 1 POINT 6:- $^{18}O\delta$ VALUE: - 0.51) (BLUE POINT ABOVE) SHOWS CLEAR SIGN OF SALINITY.

## RESULT:

Out of two set of 25 groundwater samples, 18 numbers of first set of samples and 17 numbers of second set of samples was found to be saline. But isotope analysis shows that, 2 samples, that is sample number 6 in location of malpe beach, and sample number 13 in location of kome, gopadi were affected by seawater intrusion. This study thus is important in identifying the places seawater intrusion should be countered by appropriate methods to check seawater intrusion. This improves the efficiencies of effects to control seawater intrusion.

# CHAPTER-5

# CONCLUSION AND FURTHER WORK

## 5.1: Conclusion:

Because the fresh level goes down it opens the gate for the ingress of sea water most acutely in pre monsoon when climate is dry. Unfortunately the highest demand on fresh water is particularly felt most acutely in pre monsoon.

The groundwater salinity has increased gradually with time in the wells located in the discharge area from January to march however; the groundwater salinity in the recharge area was maintained below 2 dS/mdue to the groundwater recharge in valleys and dams. This consequence of the reversibility of the intrusion process. By applying some physical and chemical criteria, it was found that wells located in malpe beach and kome, gopadi were affected by seawater intrusion.

Out of two set of 25 groundwater samples, 18 numbers of first set of samples and 17 numbers of second set of samples was found to be saline. But isotope analysis shows that, 2 samples, that is sample number 6 in location of malpe beach, and sample number 13 in location of kome, gopadi were affected by seawater intrusion. This study thus is important in identifying the places seawater intrusion should be countered by appropriate methods to check seawater intrusion. This improves the efficiencies of effects to control seawater intrusion.

## 5.2: Further work:

The effect of levels of fresh water has to be modelled to suggest alternatives by simulation. The location of interface can then be clearly demarcated.

This report can be further referred as a preliminary object for research purposes in Karnataka coastal regions.

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