MODULE 2

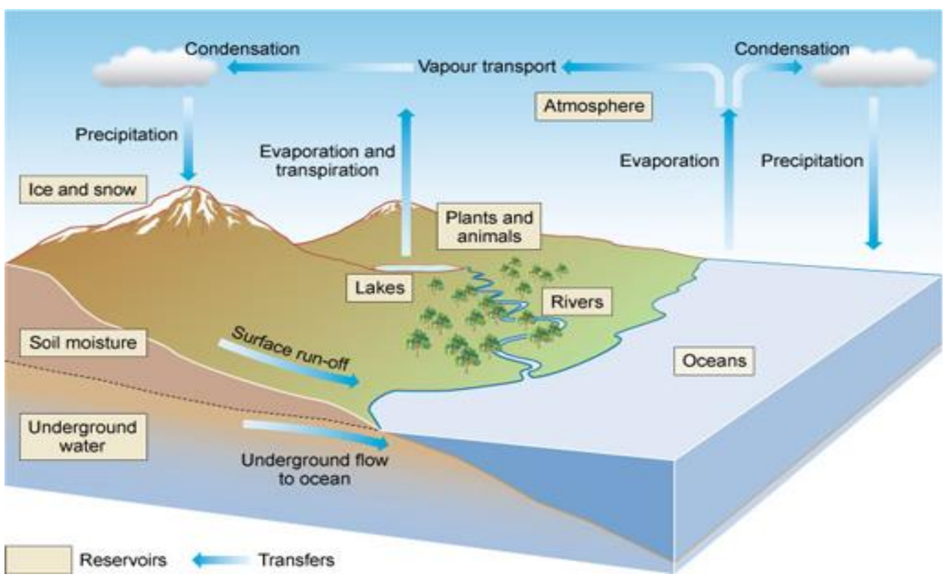
WATER

Module 2: Water

Water: Global water resources, Indian water resources, Resources system planning. Water use sectors- domestic, industrial, agriculture. Water deficit and water surplus basins in India, equitable distribution, Inter-basin water transfers, Interlinking of rivers Himalayan component, peninsular component, issues involved. Ground water, its potential in India, conjunctive use, recharge of ground water. Contamination of ground water, sea water ingress, problems and solutions.

Water

Water is an important resource available to the living organisms. It's a cradle of life on Earth. Life started on earth in water and is surviving due to the presence of water on the Earth.



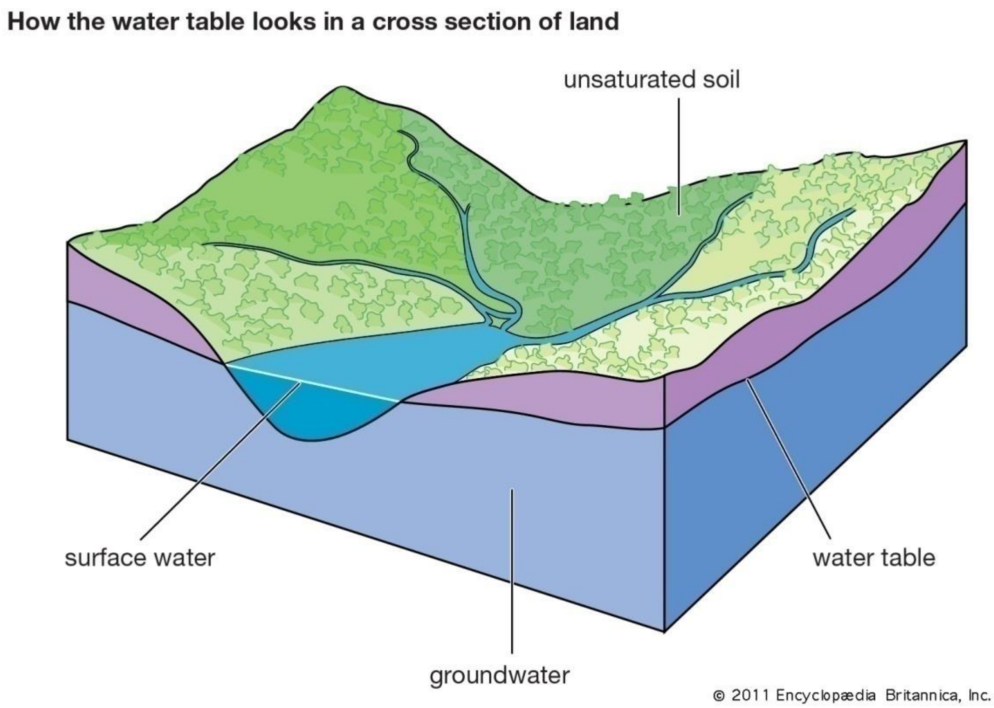
There are two main sources of water: surface water and groundwater.

- **Surface Water** is found in lakes, rivers, and reservoirs.
- **Groundwater** lies under the surface of the land, where it travels through and fills openings in the rocks.

The rocks that store and transmit groundwater are called aquifers. Groundwater must be pumped from an aquifer to the earth's surface for use

Sources of Water

1. **Rain Water**
2. **Surface Water**
3. **Ground Water**
4. **Water obtained from reclamation**



1. **Rain water**

a. From the roofs of the houses and dwellings – collected and stored in underground tank or cistern for individual supply

b. From Prepared catchments – given a suitable lining and slope, collected in small reservoirs for community supply

2. **Surface Water**

a. From rivers by continuous draft – without any diversion works.

b. From river diversions- routed through canal into treatment plant.

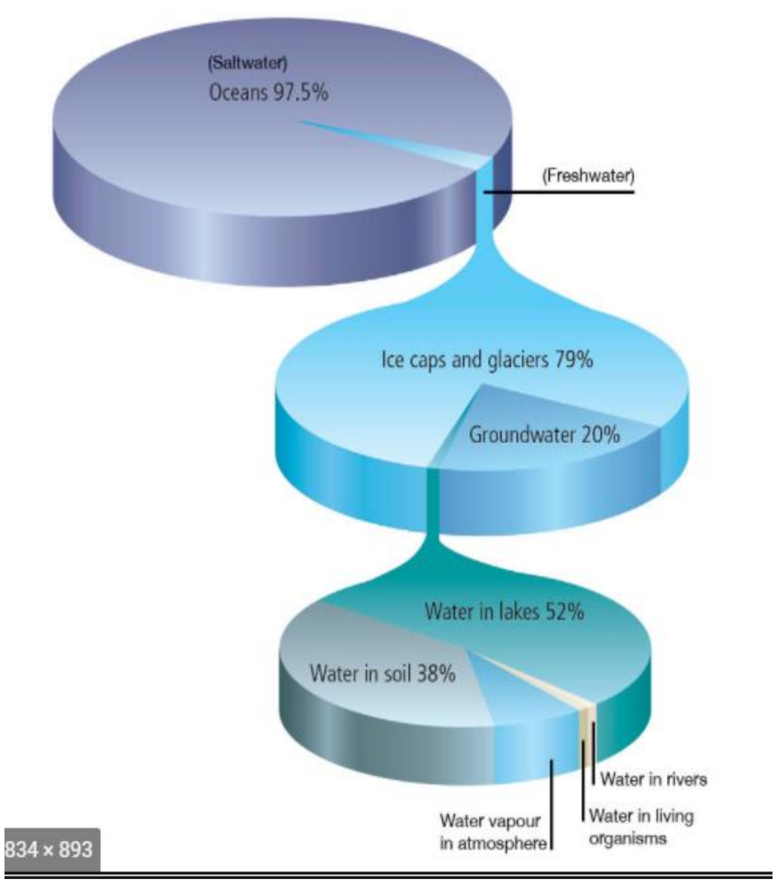
c. From reservoir storage

d. From direct intake from natural lakes

3. **Ground Water**
   a. From natural springs
   b. From wells and bore wells
   c. From infiltration galleries
   d. From river side radial collector wells

4. **Water obtained from reclamation**
   a. Desalination
   b. Re-use of treated waste water

Global Water Resources



Rivers in India

- India is blessed with many rivers. Land slope determines the river to which the rain falling on an area will eventually flow. A river basin, also called catchment area of the river, is the area from which the rain will flow into that particular river. The shape and size of the river basin is determined by the topography. Following are the major river basins groups in India.

- **Indus system**
  This comprises the river Indus and its tributaries like the Jhelum, Chenab, Ravi, Beas and Sutlej. These originate in the North and generally flow in a West or South-West direction to eventually flow into Arabian Sea through Pakistan.

- **Ganga-Brahmaputra-Meghana system**
  The main river Ganga and its tributaries like the Yamuna, Sone, Gandak, Kosi and many others; similarly main rivers Brahmaputra, Meghna and their tributaries. All these eventually flow into Bay of Bengal, through Bangladesh. Some of the tributaries of these rivers are larger than other independent rivers. e.g. Yamuna, a tributary of Ganga, has a larger catchment area than the Tapi, a small peninsula river.

- **Rivers of Rajasthan and Gujrat**
  Mahi, Sabarmati, Luni etc. These are rivers of arid regions, they carry relatively little flow, some of them flow to Arabian Sea through Gujrat while some are land-locked and their flow is lost through percolation and evaporation in the vast arid regions.

- **East Flowing Peninsular Rivers**
  The important membes of this group are :Damodar, Mahanadi, Brhamanai, Baitrani, Subarnarekha, Krishna-Godavari and Kaveri. The all flow in to Bay of Bengal at various places along the Eastern coast of India.

- **West Flowing Peninsular Rivers**
  Narmada and Tapi. These originate in Central India and flow in a Western direction to meet Arabian Sea south of Gujrat.

- **Western Coast Rivers**
  A large number of rivers in the Western Coast – i.e. coastal Maharashtra and Karnatka, and entire Kerala. These rivers are small in length but carry a significant amount of water due to very high rainfall in western ghats. They drain only 3 % of the India’s land area but carry 11 % of India’s water resources

Uses of Water

Productive use: water is primarily used for irrigation of food crops, fodder crops, medicinal herbs, etc. Consumptive use: water is consumed in exhaustive quantities for domestic purposes such as drinking, cooking, washing etc. water find its application in almost all the processes in industries, starting from the manufacturing processes to housekeeping activities. Commercial use: Water consumed for carrying out commercial and recreational activities.

Many uses of water include agricultural, industrial, household, recreational and environmental activities. Virtually all of these human uses require fresh water. The framework for allocating water resources to water users (where such a framework exists) is known as water rights

- Agricultural:

It is estimated that 69% of world-wide water use is for irrigation. In some areas of the world irrigation is necessary to grow any crop at all, in other areas it permits more profitable crops to be grown or enhances crop yield.

- Industrial

It is estimated that 15% of world-wide water use is industrial. Major industrial users include power plants, which use water for cooling or as a power source (i.e. hydroelectric plants), ore and oil refineries, which use water in chemical processes, and manufacturing plants, which use water as a solvent. The portion of industrial water usage that is consumptive varies widely, but as a whole is lower than agricultural use

- Household Drinking water

It is estimated that 15% of world-wide water use is for household purposes. These include drinking water, bathing, cooking, sanitation, and gardening. Basic household water requirements have been estimated at around 50 liters per person per day, excluding water for gardens.

- Recreation

Recreational water use is usually a very small but growing percentage of total water use. Recreational water use is mostly tied to reservoirs. If a reservoir is kept fuller than it would otherwise be for recreation, then the water retained could be categorized as recreational usage. Other examples are anglers, water skiers, nature enthusiasts and swimmers.

Water Deficit

India has 1/6th of the global population and 1/25th of world's water resources, but the water availability is highly uncertain both in time and space due to its peculiar monsoonal climate.

About 70 % of the population directly or indirectly depends on agriculture, in the back drop of economic growth from industrialization. The urban population in the country is increasing at faster rate which requires the establishment of basic infrastructure, amenities and increase in food production. It is essential to convert rain fed crops into irrigation crops

The irrigation commission in 1972 has identified 67 drought prone districts comprising 326 taluks located in 8 states having an area of 49.73 M Ha. The revised study made by Central Water Commission (CWC) in 2006 reveals that 51.12 M Ha area is drought affected in 74 districts. Thus in comparison to total geographical area of the country about 1/6th is drought prone area

As per international standards per capita water requirement is 1700 m3 per year. If the availability is less than 1000 m3, it is considered as water scarcity. If it ranges between 1000-1700 m3 it is treated as water stressed. India with present availability of about 1600 m3 is under water stress condition

Inter Basin Water Transfer

The concept of the Inter basin water transfer is to be explored and implemented to ensure uniform distribution of available natural water resource and to mitigate the consequences of hydrologic extremes of floods and droughts.

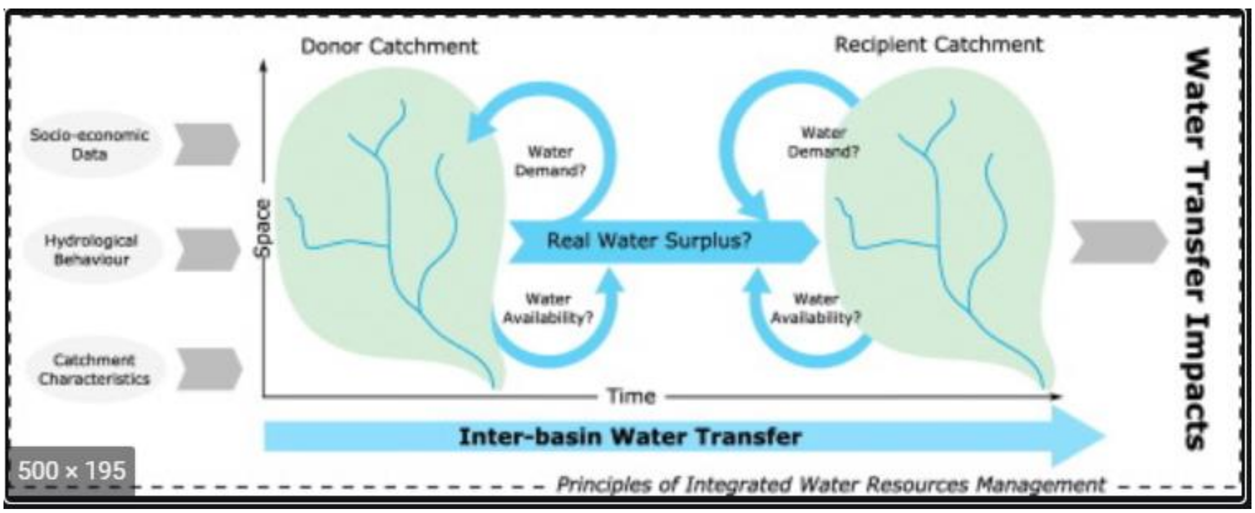
The implementation of Inter basin water transfer is the need of the hour for the overall development of a country like India in which population is growing at an alarming rate. Also the Inter basin water transfer helps to prevent the formation of deltas along the coast line and migration of people from drought affected region

In India the monsoons are highly orographic causing floods in North and North Eastern region and drought in other areas. The solution for storage and transfer lies in much talked about interlinking of rivers or inter basin water transfer. As the Govt. of India is spending huge amount of money every year towards the relief of floods and drought, it is worthwhile to spend on inter basin and intra basin water transfer schemes keeping long term benefits in view. Moreover the inter basin water transfer is the only solution to maintain regional balance in all sectors like Agricultural, Industrial, Power generation, Domestic, Navigation etc

Examples of Inter basin water transfer in India

- Periyar - Vaigai project (Kerala state 1985)
- Kurnool – - Cuddapah Canal (Andhra Pradesh 1863-1870)
- Parambikulam - Aliyar project (1962-82)

- Telugu – - Ganga project
- Beas – - Sutlej Link (1983)
- Indira Gandhi Nahar project (Rajasthan canal, 1958)
- Sarada - Sahayak Project (1960)
- Ramganga – - Ganga Link (1978)
- Tungabhadra – - Pennar project
- Mahi project
- Tehri Multipurpose project



Inter linking of Rivers

NWDA (National Water Development Agency) was formed in 1980 to further investigate and explore the possibilities of interlinking of rivers. The broad objectives of NWDA are

1. To promote systematic and scientific study of interlinking of rivers.
2. To carryout detailed study, survey, investigations of Peninsular and Himalayan rivers.
3. To identify possible water transfer projects/links to carry water from surplus basin to deficit one after meeting the existing and proposed needs.

4. To prepare feasibility reports of various components of Himalayan and Peninsular rivers.

After thorough investigations NWDA proposed to transfer water through 12,500 Km length of canal. As per NWDA, Inter basin water transfer is proposed in two components namely

(1) Himalayan component and

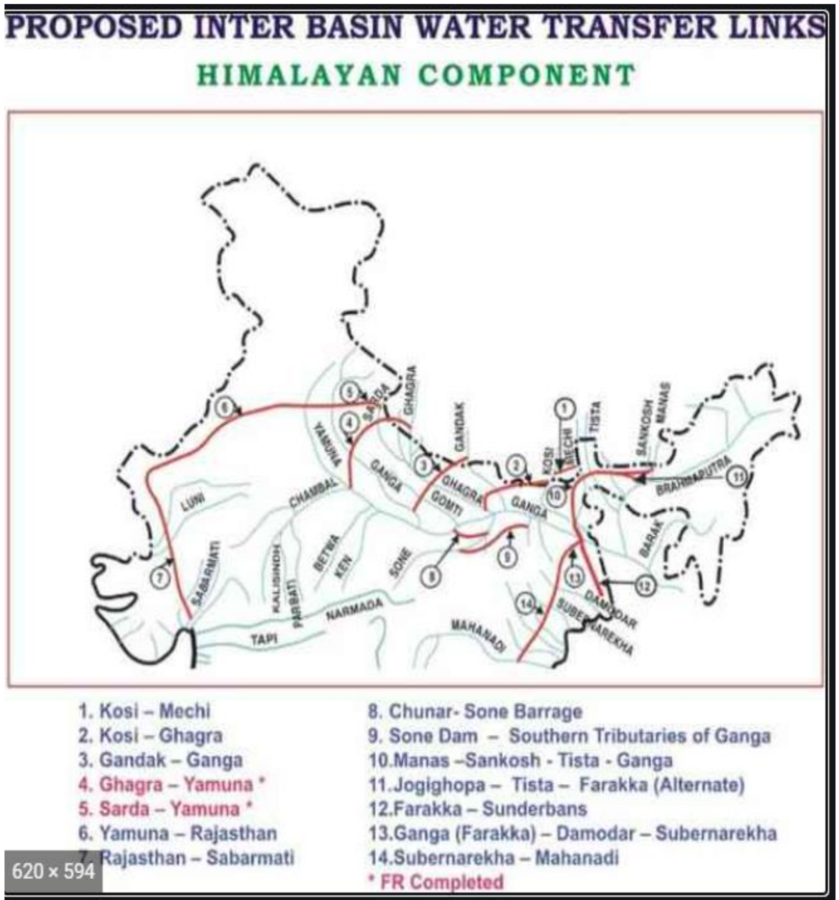
(2) Peninsular component.

1. Himalayan Component

   This component mainly proposes to link Brahmaputra and its tributaries with the river Ganga and Ganga with Mahanadi. In addition it also proposes to transfer surplus flows of the Eastern tributaries of Ganga to the West. This component envisages construction of canal systems and storage reservoirs on the principal tributaries of Ganga and Brahmaputra rivers in India, Nepal and Bhutan. This component would provide additional irrigation to about 22 MHa and power generation of about 30000 MW besides flood control in Brahmaputra and Ganga basins

Table 4: Himalayan Component

1 Brahmaputra-Ganga	6 Yamuna-Rajastana
2 kosi-Ghagra	7 Rajastana-Sabaramati
3 Gandak-Ganga	8 Chemar- Sone barrage link
4 Ghagra- Yamuna	9 Sone dam-southern Ganga
5 Sarada-Yamuna	10 Ganga –Damodar – Subernarekha
11Subernarekha-Mahanadi	13 Farakka-Sunderban
12 Kosi-Mechi	14 Brahmaputra-Ganga(Jogighopa-Tista-Farakka)



2. **Peninsular Component**

In this component a network of interconnected river basins of Peninsular India is considered. NWDA carried out water balance studies of all the major river basins such as Mahanadi , Godavari , Krishna ,Pennar , Cauvery , Vaigai, West flowing rivers of Kerala , Karnataka , North of Bombay and South of Tapi and Southern tributaries of Yamuna to find out water surplus and deficit basins. The 16 links of Peninsular component are given below

15.Mahanadi (Manibhadra) - Godavari (Dowleswaram) Link	23.Cauvery (Kattalai) - Vaigai - Gundar Link
16.Godavari (Inchampalli) - Krishna (Nagarjunasagar) Link	24.Ken - Betwa Link
17.Godavari (Inchampalli Low Dam) - Krishna (Nagarjunasagar Tail pond) Link	25.Parbathi - kalisindh Link
18.Godavari (Polavaram) - Krishna (Vijayawada Link)	26.Par - Tapi - Narmada
19.Krishna (Almatti) - Pennar (Bukkapatnam) Link	27.Damanganga - Pinjal Link
20.Krishna (Srisailam) - Pennar (Mylavaram)Link	28.Bedti - Varda Link
21.Krishna (Nagarjunasagar) - Pennar (Somasila)Link	29.Netravathi - Hemavathi Link
22.Pennar (Somasila) - Cauvery (Grand Anicut) Link	30.Pamba-Achankovil - Vaippar Link

- From Peninsular Component it is possible to irrigate about 13 M Ha and about 4000 MW of Hydropower can be generated. The Peninsular component utilizes 69.6 TMCum of water. This component involves the construction of storage reservoirs at potential sites in addition to the existing /ongoing reservoirs and a network of canals for water transfer

Table 6: salient features of inter basin water transfers in india

1.	Additional Irrigation	:	35 M Ha
2.	Hydropower generation	:	34000 to 40000 MW
3.	The Cost of the project	:	Rs 5,60,000 crores (as per 2002 estimate)
4.	Water utilization	:	20.96 MHa m
5.	Execution period	:	40 years
6.	Agricultural production	:	250 to 450 Million Tons

7.	Total length of canals	:	10880 Km
8.	Cost per Ha	:	Rs 75000
9.	Water availability	:	1122 m3 / capita / year
10.	Flood control		
	Area can be protected	:	About 40 M Ha
	Population protected	:	About 260 Million
	Financial savings	:	About 1200 crores per year
11.	Drought protection		
	Population benefited	:	About 86 Million
	States benefited	:	14
	Districts benefited	:	116
	Financial benefit	:	About 1200 crores per year
12.	Rivers involved	:	37
13.	Reservoirs involved	:	60

Merits of Inter Basin Water Transfer

1. Possible to utilize the water resources uniformly and economically to yield Significant output.
2. Enhancement in Irrigation potential and power generation
3. Provides ample surface water to meet the growing needs of Domestic and Industries.
4. Scopes for Inland Navigation which reduces stress on existing communication system.
5. It minimizes the intensity of drought and floods.
6. It helps to increase per capita income
7. Reduces the exploitation of ground water as surface water is made available in abundant.
8. Huge employment generation
9. Development of fisheries
10. Salinity control
11. Recreation facility
12. . Infrastructural development

13. Socio economic development

14. Considerable improvement in ground water potential

15. Control in migration

16. Conversion of barren land into cultivable land

17. Reduction in formation of further deltas in coastal zones.

18. Minimization of the relief expenditure towards floods and droughts

[Note: explain each point in your own words in a sentence or two]

Demerits of Inter Basin Water Transfer

1. Large area liable for submersion due to construction of reservoirs and canals
2. Adverse effects over ecological system
3. Difficult to solve Interstate or International water disputes
4. Legal problem in sharing the water
5. Cost of the project and recurring expenditure for maintenance are high
6. Water pollution in conveyance
7. Loss of water in conveyance through the canals
8. Land acquisition and rehabilitation problems
9. Requires afforestation to compensate for loss in green
10. It is a long term project which may cause large variation in estimation
11. Serving for high altitude areas needs pumping of water which requires huge power and maintenance.

12. Needs huge debate at micro level and macro level on the issue to convince the public.

13. Problems of soil erosion and sedimentation

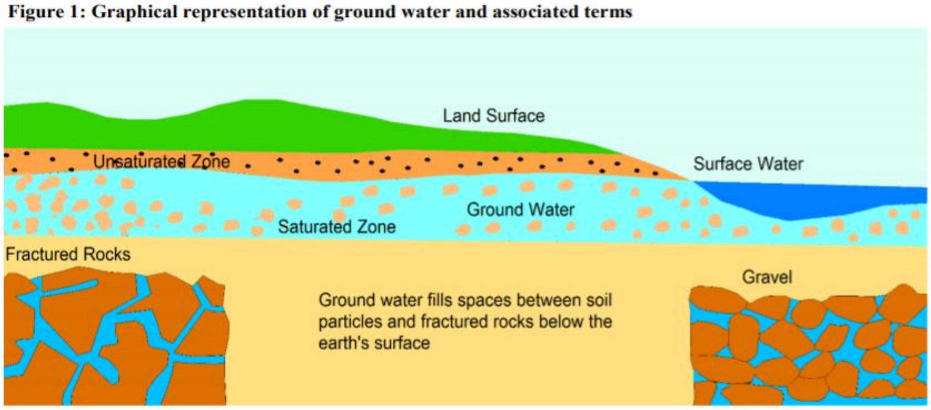
14. In undulated zones it may required to construct large number of cross drainage works.

[Note: explain each point in your own words in a sentence or two]

Ground Water

Ground water is the water that seeps through rocks and soil and is stored below the ground. The rocks in which ground water is stored are called aquifers. Aquifers are typically made up of gravel, sand, sandstone or limestone. Water moves through these rocks because they have large connected spaces that make them permeable. The area where water fills the aquifer is called the saturated zone. The depth from the surface at which ground water is found is called the water table. The water table can be as shallow as a foot below the ground or it can be a few hundred meters deep. Heavy rains can cause the water table to rise and conversely, continuous extraction of ground water can cause the level to fall

Figure 1: Graphical representation of ground water and associated terms



Ground Water Potential in India

1. **Hard-rock aquifers of peninsular India:**

- These aquifers represent around 65% of India's overall aquifer surface area.

- Most of them are found in central peninsular India, where land is typically underlain by hard-rock formations.
- These rocks give rise to a complex and extensive low-storage aquifer system, where in the water level tends to drop very rapidly once the water table falls by more than 2-6 meters.
- These are located south of Indo-Gangetic-Brahmaputra plains and consist mostly of consolidated sedimentary rocks, Deccan Trap basalts and crystalline rocks in the states of Karnataka, Maharashtra, and Tamil Nadu, Andhra Pradesh, Orissa and Kerala. Occurrence and movement of ground water in these formations are restricted to weathered residuum and interconnected fractures at deeper levels and they have limited ground water potential. The rocks are commonly weathered to a depth of 30m under the tropical conditions in central and southern part of the peninsular region.
- Ground water occurs mainly in the weathered and fractured zones of rocks, within depth of less than 50m, occasionally down to 100m, and rarely below this depth. Locally deep circulation of ground water is indicated, as instanced by striking solution cavities or deeper water bearing fractures. Ground water development is largely through dug wells. The valley fills in this region are often dependable sources of water supply. The yield of wells tapping deeper fractured zones in hard rocks varies from 2-10 lps.

2. Alluvial aquifers of the Indo-Gangetic plains:

- These aquifers, found in the Gangetic and Indus plains in Northern India have significant storage spaces, and hence are a valuable source of fresh water supply.
- However, due to excessive ground water extraction and low recharge rates, these aquifers are at the risk of irreversible overexploitation.
- This region encompasses an area of about 850,000 sq km covering states of Punjab, Haryana, Uttar Pradesh, Bihar, Assam and West Bengal, accounting for more than one

fourth of country’s land area, comprises the vast plains of Ganges and Brahmaputra rivers and are underlain by thick piles of sediments of Tertiary and Quaternary age.

- This vast and thick alluvial fill, exceeding 1000 m at places, constitute the most potential and productive ground water reservoir in the country. These are characterized by regionally extensive and highly productive multi-aquifer systems. The ground water development in this region is still sub-optimal, except in the states of Haryana and Punjab. The deeper aquifers available in these areas offer good scope for further exploitation of ground water with suitable Fig.2. Hydrogeology of India measures. In Indo-Gangetic- Brahmaputra plain, the deeper wells have yield ranging from 25-50 lps.

3. Northern Mountainous Terrain and Hilly areas:

- The highly rugged mountainous terrain in the Himalayan region in the northern part of the country extending from Kashmir to Arunachal Pradesh is characterized by steep slopes and high runoff.
- This region is underlain mostly by rocks such as granites, slate, sandstone and lime stone ranging in age from Paleozoic to Cenozoic. The yield potential ranges from 1 to 40 lps. Though this area offers very little scope for groundwater storage, it acts as the major source of recharge for the vast Indo-Gangetic and Brahmaputra alluvial plains.

4. Coastal Area

- Coastal areas have a thick cover of alluvial deposits of Pleistocene to Recent age and form potential multi-aquifer systems in the states of Gujarat, Kerala, Tamil Nadu, Andhra Pradesh and Orissa.
- However, inherent quality problems and the risk of seawater ingress impose severe constrains in the development of these aquifers.

- In addition, the ground water overdevelopment in these areas entails the risk of saline water ingress. Ground water prospects in these aquifers vary widely depending on the local conditions and may range from 5-25 lps

Ground water availability

As of April 2015, the water resource potential or annual water availability of the country in terms of natural runoff (flow) in rivers is about 1,869 Billion Cubic Meter (BCM)/year. However, the usable water resources of the country have been estimated as 1,123 BCM/year. This is due to constraints of topography and uneven distribution of the resource in various river basins, which makes it difficult to extract the entire available 1,869 BCM/year.

Conjunctive use of Ground Water and Surface Water

Conjunctive water use refers to simultaneous use of surface water and groundwater to meet crop demand. Each day, hundreds of thousands of farmers in canal, tank, and other surface irrigation systems combine surface water with groundwater. They do so in an individual manner, uncontrolled by any scheme or basin-level entity.

To optimize conjunctive use of water, the best way forward is to concentrate on capacity building of irrigation system. To sustain groundwater use in tubewell-irrigated areas, enhancing recharge from precipitation and surface water imports is necessary

Management of Ground Water

Management of ground water resources in the Indian context is an extremely complex proposition as it deals with the interactions between the human society and the physical environment. The highly uneven distribution of ground water availability and its utilization indicates that no single management strategy can be adopted for the country as a whole. On the other hand, each situation demands a solution which takes into account the geomorphic set-up, climatic, hydrologic and hydrogeologic settings, ground water availability, water utilization pattern for various sectors and the socio-economic set-up of the region.

Ground Water Depletion

Indiscriminate ground water development has led to substantial ground water level declines both in hard rocks and alluvial areas threatening sustainability of this resource. Long-term decline of ground water levels is being observed in many areas, mostly in the states of Rajasthan, Gujarat, Tamil Nadu, Punjab, Delhi and Haryana. Apart form this, in most of the cities depending on ground water for drinking water supplies, water level declines up to 30 m and more have been observed. Traditional water harvesting methods, which were in vogue in arid and semi-arid areas of the country have either been abandoned or have become defunct in most cases. There is an urgent need to revive these methods.

Contamination of Ground Water

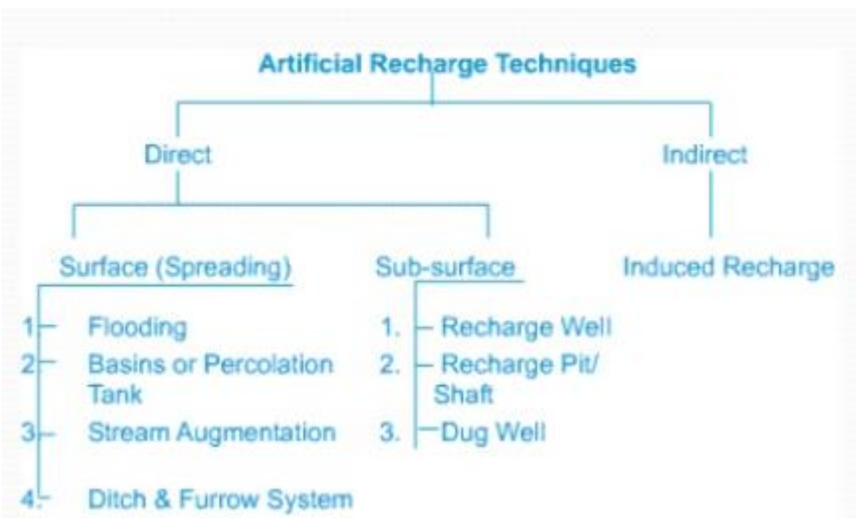
Ground water contamination is the presence of certain pollutants in ground water that are in excess of the limits prescribed for drinking water. The commonly observed contaminants include arsenic, fluoride, nitrate and iron, which are geogenic in nature. Other contaminants include bacteria, phosphates and heavy metals which are a result of human activities including domestic sewage, agricultural practices and industrial effluents. The sources of contamination include pollution by landfills, septic tanks, leaky underground gas tanks, and from overuse of fertilizers and pesticides. It has been pointed out that nearly 60% of all districts in the country have issues related to either availability of ground water, or quality of ground water, or both.

Recharge of Ground Water

Flow below the land surface takes place due to the process of infiltration. The recharge of aquifers takes place during the precipitation due to infiltration of water into the pores in the soil strata. The soil will not get completely saturated with water unless water supply is maintained for prolonged periods. If water is applied only intermittently, there may be no recharge during the first infiltration or even between two subsequent infiltrations.

Artificial Recharge of Ground Water

Natural replenishment of ground water reservoir is a slow process and is often unable to keep pace with the excessive and continued exploitation of ground water resources in various parts of the country. This has resulted in declining ground water levels and depletion of ground water resources in such areas. Artificial recharge aims at augmenting the natural replenishment of ground water storage by some method of construction, spreading of water, or by artificially changing natural conditions. It is useful for reducing overdraft, conserving surface run-off, and increasing available ground water supplies. Recharge may be incidental or deliberate, depending on whether or not it is a by-product of normal water utilization. Artificial recharge can also be defined as a process of induced replenishment of the ground water reservoir by human activities. The process of supplementing may be either planned such as storing water in pits, tanks etc. for feeding the aquifer or unplanned and incidental to human activities like applied irrigation, leakages from pipes etc



Seawater Ingress in Coastal Aquifers

The unconsolidated deltaic and coastal sediments form thick and regionally extensive aquifers having prolific yield potential that can sustain deep, moderate to high capacity tube wells. Although considerable fresh ground water resources have been identified in regionally extensive deltaic and coastal tracts, particularly along the east coast, inherent quality problems restrict their development. The ground water in these aquifers exists in a fragile dynamic equilibrium with seawater. Indiscriminate exploitation of ground water from such aquifers can disturb this equilibrium and result in the development of landward hydraulic gradient, ultimately leading to seawater intrusion into the fresh water aquifers. Coastal aquifers in parts of Gujarat, Tamil Nadu and Andhra Pradesh are already suffering from the problem of salinity ingress.

Measures to prevent/control saline water intrusion into coastal aquifers include

i) Regulation of ground water development in coastal areas.

ii) Formation of a freshwater ridge parallel to the coast through artificial recharge.

iii) Formation of a pumping trough through a series of pumping wells aligned parallel to the coast

iv) Reduce Water use

v) Reduce Pump depth

vi) Pump less water more frequently

vii) Well location to be at least 50m from the coast

viii) Avoid deep wells close to the coast