1. **Explain Global Water Resources along with its Challenges**

(10 Marks – VTU Answer Format)

Introduction

Water is one of the most vital natural resources essential for the survival of all living organisms. Life on Earth originated in water and continues to depend on it for domestic, agricultural, industrial, and ecological needs. However, although water appears abundant, only a very small fraction is available for direct human use, making proper understanding and management of **global water resources** extremely important

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Global Water Resources

Global water resources refer to the total quantity of water available on Earth in different forms such as oceans, ice caps, groundwater, surface water, and atmospheric water.

- About **97.5% of the Earth's water** is saline and present in oceans, which is not directly suitable for drinking or irrigation.
- Only **2.5% of total water is freshwater**.
- Of this freshwater:
    - Nearly **79%** is locked in **ice caps and glaciers**.
    - Around **20%** exists as **groundwater** stored in aquifers.
    - Less than **1%** is available as **surface water** in rivers, lakes, reservoirs, soil moisture, and atmosphere.
- Surface water found in **rivers and lakes** forms the most accessible source for human use, though it constitutes the smallest fraction of global freshwater.
- Groundwater stored in aquifers plays a crucial role in meeting drinking water and irrigation demands across the world

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Thus, although Earth is called a “water planet,” the amount of usable freshwater is extremely limited.

Challenges Associated with Global Water Resources

1. **Uneven Distribution**
   Water availability is highly uneven across regions and seasons. Some areas receive excessive rainfall causing floods, while others suffer from chronic droughts due to scarcity.
2. **Population Growth**
   Rapid population growth has significantly increased the demand for water for drinking, sanitation, agriculture, and industry, putting enormous pressure on limited freshwater resources.
3. **Agricultural Water Demand**
   Agriculture alone consumes nearly **70% of global freshwater**, mainly for irrigation. Inefficient irrigation practices lead to large-scale wastage of water.
4. **Industrialization and Urbanization**
   Expanding industries and urban centers require huge quantities of water for manufacturing, cooling, and domestic use, reducing availability for other sectors.
5. **Groundwater Depletion**
   Excessive extraction of groundwater beyond natural recharge rates has resulted in declining water tables in many regions, threatening long-term sustainability.
6. **Water Pollution**
   Discharge of untreated industrial effluents, sewage, agricultural runoff, and chemicals contaminates rivers, lakes, and groundwater, reducing the amount of safe usable water.
7. **Climate Change**
   Climate change alters rainfall patterns, increases glacier melting, and intensifies extreme events like floods and droughts, making water availability uncertain.
8. **Inadequate Management and Infrastructure**
   Poor water governance, lack of storage facilities, and inefficient distribution systems further aggravate water scarcity problems.

2. **Explain Indian Water Resources along with its Challenges**

(10 Marks – VTU Answer Format)

Introduction

India is endowed with considerable water resources in the form of rivers, rainfall, surface water bodies, and groundwater. However, due to its vast population, monsoon-dependent climate, and uneven geographical distribution, effective utilization and management of **Indian water resources** has become a major challenge. Understanding the nature of these resources and the problems associated with them is essential for sustainable development

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Indian Water Resources

Indian water resources mainly consist of **surface water** and **groundwater**, derived largely from rainfall.

1. **Rainfall**
    - India receives most of its rainfall from the **south-west monsoon**.
    - Rainfall is highly seasonal and unevenly distributed, causing floods in some regions and droughts in others.
2. **Surface Water Resources**
    - Surface water is available in the form of **rivers, lakes, reservoirs, and tanks**.
    - India is drained by several major river systems, broadly classified as:
        - **Indus River System**
        - **Ganga–Brahmaputra–Meghna System**
        - **East-flowing Peninsular Rivers** (Godavari, Krishna, Cauvery, Mahanadi)
        - **West-flowing Rivers** (Narmada, Tapi)

        - **Western Coastal Rivers**
    - These rivers support irrigation, drinking water supply, hydropower generation, navigation, and industrial use

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3. **Groundwater Resources**
    - Groundwater is stored in **aquifers** and forms a major source of drinking and irrigation water.
    - India has both **hard-rock aquifers** (peninsular India) and **alluvial aquifers** (Indo-Gangetic plains).
    - Groundwater plays a crucial role during dry seasons and droughts.
4. **Water Availability**
    - India has about **1/6th of the world's population** but only **1/25th of global water resources**.
    - Per capita water availability is decreasing and currently places India under **water-stressed conditions**

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Challenges of Indian Water Resources

1. **Uneven Spatial and Temporal Distribution**
    - Water availability varies widely across regions and seasons due to monsoon dependency.
2. **Water Scarcity and Stress**
    - As per international standards, India's per capita water availability (~1600 m^3/year) indicates **water stress**, and it may reach scarcity levels in the future.
3. **Over-exploitation of Groundwater**

- Excessive withdrawal for agriculture and urban use has led to rapid decline in groundwater levels in many states.

4. **Floods and Droughts**
    - Northern and northeastern regions experience floods, while central and southern regions often face droughts, causing imbalance in water availability.
5. **Water Pollution**
    - Rivers and groundwater are polluted due to industrial effluents, sewage discharge, agricultural runoff, and solid waste dumping.
6. **Inter-State Water Disputes**
    - Sharing of river water among states often leads to conflicts, delaying effective water resource development.
7. **Population Growth and Urbanization**
    - Rapid population growth increases demand for drinking water, sanitation, agriculture, and industrial activities.
8. **Poor Water Management**
    - Inefficient irrigation methods, leakage losses, and inadequate storage infrastructure result in wastage of available water.

3. **Explain how Resource System Planning helps in Conservation of Water Resources**

(10 Marks – VTU Answer Format)

Introduction

Water is a finite and vital natural resource whose availability is highly uneven in time and space, especially in countries like India that depend largely on monsoon rainfall. Rapid population growth, agriculture expansion, industrialization, and urbanization have increased pressure on available water resources. **Resource system planning** plays a crucial role in the systematic development, utilization, and conservation of water resources to ensure sustainability and equitable distribution

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Resource System Planning

Resource system planning refers to a scientific and integrated approach for assessing, developing, allocating, and managing water resources within a river basin or region by considering surface water, groundwater, demand sectors, and environmental needs together.

Role of Resource System Planning in Conservation of Water Resources

1. **Optimal Utilization of Available Water**
    - Resource system planning ensures optimal use of surface water and groundwater by avoiding over-extraction and wastage.
    - It promotes efficient allocation among domestic, agricultural, industrial, and ecological sectors.
2. **Integrated Management of Surface and Groundwater**
    - Planning emphasizes **conjunctive use** of surface water and groundwater, reducing stress on any single source.
    - This helps maintain groundwater levels and improves long-term water availability.
3. **Equitable Distribution of Water**
    - Resource system planning ensures fair distribution of water between water-surplus and water-deficit regions.
    - It supports inter-basin water transfer schemes to balance regional water availability.
4. **Reduction of Floods and Drought Impacts**
    - By incorporating storage reservoirs, canals, and flood moderation measures, planning minimizes flood damages.
    - During dry periods, stored water helps mitigate drought conditions.
5. **Improved Irrigation Efficiency**

- Planning encourages efficient irrigation methods and conversion of rain-fed areas into irrigated areas.
- This reduces excessive water withdrawal and enhances agricultural productivity.

6. **Water Conservation through Storage and Harvesting**
    - Construction of reservoirs, tanks, and rainwater harvesting structures helps conserve excess monsoon runoff.
    - Stored water can be utilized during lean seasons.
7. **Protection of Water Quality**
    - Resource system planning includes pollution control measures and proper wastewater management.
    - This prevents contamination of surface water and groundwater resources.
8. **Sustainable Development and Long-Term Planning**
    - Planning considers future population growth, climate variability, and environmental requirements.
    - This ensures sustainable use of water resources for future generations.

4. **Explain the Different Water Using Sectors in India**

(10 Marks – VTU Answer Format)

Introduction

Water is a critical natural resource that supports economic development, food security, public health, and environmental sustainability. In India, water is utilized by various sectors depending on their functional requirements. The major **water using sectors in India** include agricultural, industrial, domestic, and recreational sectors. Proper understanding of these sectors is essential for efficient water resource planning and management

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Different Water Using Sectors in India

1. Agricultural Sector

- Agriculture is the **largest consumer of water in India**, accounting for nearly **69% of total water use**.
- Water is mainly used for **irrigation of food crops, fodder crops, and cash crops**.
- Irrigation helps convert rain-fed agriculture into assured crop production systems, increasing yield and food security.
- Major irrigation sources include rivers, reservoirs, canals, tanks, and groundwater through wells and bore wells.
- Inefficient irrigation practices often lead to excessive water consumption and groundwater depletion

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2. Industrial Sector

- The industrial sector accounts for about **15% of total water usage**.
- Water is used in:
    - Cooling processes (thermal and nuclear power plants)
    - Manufacturing and processing industries
    - Chemical reactions and washing operations
- Major water-consuming industries include **power plants, refineries, steel plants, paper mills, textile and chemical industries**.
- Although industrial water use is less consumptive than agriculture, improper disposal leads to water pollution

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3. Domestic (Household) Sector

- Domestic water use constitutes around **15% of total water consumption**.
- Water is used for:
    - Drinking
    - Cooking
    - Bathing
    - Washing and cleaning
    - Sanitation and gardening
- The basic domestic water requirement is estimated at **about 50 litres per person per day**, excluding water used for gardening.
- Rapid urbanization and population growth have significantly increased domestic water demand in cities and towns

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4. Recreational Sector

- Recreational water use forms a **small but growing share** of total water consumption.
- Water is used for:
    - Parks and gardens
    - Swimming pools
    - Boating and water sports
    - Fishing and tourism-related activities
- Recreational use is often associated with **reservoirs and lakes**, where maintaining water levels enhances tourism and recreation.
- Though limited in quantity, this sector contributes to social well-being and economic development

5. **Explain Briefly Sustainable Water Use**

(10 Marks – VTU Answer Format)

Introduction

Water is a limited and essential natural resource required for domestic, agricultural, industrial, and ecological needs. Increasing population, urbanization, industrial growth, and climate variability have put severe pressure on available water resources. **Sustainable water use** refers to the judicious, efficient, and long-term utilization of water resources in a manner that meets present needs without compromising the ability of future generations to meet their own water requirements

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Sustainable Water Use

Sustainable water use involves managing surface water and groundwater resources in an integrated manner, ensuring optimal utilization, conservation, equitable distribution, and protection of water quality while maintaining ecological balance.

Key Aspects of Sustainable Water Use

1. **Efficient Utilization of Water**
    - Adoption of water-saving technologies and practices in agriculture, industry, and domestic sectors.
    - Reduction of losses due to leakage, evaporation, and inefficient usage.
2. **Conservation of Water Resources**
    - Rainwater harvesting and storage of excess monsoon runoff for use during dry periods.
    - Promotion of water reuse and recycling, especially in urban and industrial areas.
3. **Conjunctive Use of Surface and Groundwater**

- Balanced use of surface water and groundwater to prevent over-exploitation of aquifers.
- Helps maintain groundwater levels and ensures long-term water availability.

4. **Protection of Water Quality**
    - Prevention of pollution by controlling discharge of untreated sewage, industrial effluents, and agricultural chemicals.
    - Ensuring availability of safe and clean water for all uses.
5. **Equitable Distribution of Water**
    - Fair allocation of water among different sectors and regions, including water-surplus and water-deficit areas.
    - Reduces regional disparities and water-related conflicts.
6. **Sustainable Agricultural Practices**
    - Use of efficient irrigation methods such as controlled water application.
    - Encouragement of cropping patterns suitable to local water availability.
7. **Long-Term Planning and Management**
    - Consideration of population growth, climate change, and environmental needs in water resource planning.
    - Ensures water security for present and future generations.

6. **Explain the Water Deficit in India**

(10 Marks – VTU Answer Format)

Introduction

India faces a serious **water deficit** despite having several rivers and substantial rainfall. This is mainly due to uneven distribution of water resources, monsoon dependency, rapid population growth, and increasing demands from agriculture, industry, and domestic sectors. Water deficit refers to a condition where **water demand exceeds the available supply** in a region over a given period

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Water Deficit in India

India has about **one-sixth of the world's population** but only **one-twenty-fifth of the global water resources**. The availability of water is highly uncertain in both **time and space** due to its monsoonal climate. Large parts of the country experience seasonal or chronic water shortages, leading to water-stressed and water-scarce conditions

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Causes of Water Deficit in India

1. **Uneven Distribution of Rainfall**
    - Rainfall in India is highly irregular and concentrated during a short monsoon period.
    - Some regions receive excessive rainfall causing floods, while others receive very little, resulting in droughts.
2. **Monsoon Dependency**
    - Indian water availability depends heavily on monsoons.
    - Failure or delay of monsoon leads to severe water shortages, especially in rain-fed regions.
3. **High Population Pressure**
    - Rapid population growth has increased demand for drinking water, sanitation, food production, and industrial use.
4. **Agricultural Dominance**
    - Nearly **70% of India's population depends on agriculture**, which consumes the largest share of water for irrigation.
    - Conversion of rain-fed crops into irrigated crops has increased water demand significantly.

5. **Urbanization and Industrialization**
    - Rapid urban growth requires large quantities of water for domestic and industrial purposes.
    - Expansion of infrastructure and industries further stresses available water resources.
6. **Drought-Prone Areas**
    - The Irrigation Commission (1972) identified **67 drought-prone districts** covering about **49.73 million hectares**.
    - A revised study by the Central Water Commission (2006) showed **51.12 million hectares** in **74 districts** affected by drought, which is nearly **one-sixth of India's total geographical area**

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7. **Declining Per Capita Water Availability**
    - As per international standards, a per capita availability of **1700 m^3/year** is considered adequate.
    - Availability below **1000 m^3/year** indicates water scarcity.
    - India's present per capita availability is about **1600 m^3/year**, placing the country under **water-stressed condition**

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Impacts of Water Deficit

- Reduced agricultural productivity and crop failures
- Drinking water shortages in rural and urban areas
- Increased dependence on groundwater leading to depletion
- Migration from drought-affected regions
- Socio-economic stress and conflicts over water sharing

7. **xplain the Water Surplus Basins of India**

(10 Marks – VTU Answer Format)

Introduction

India receives substantial rainfall annually, but the availability of water is unevenly distributed across regions due to variations in climate, topography, and river systems. **Water surplus basins** are river basins where the availability of water exceeds the present and projected demand even after meeting irrigation, domestic, industrial, and ecological requirements. Identification of such basins is essential for effective water resource planning and inter-basin water transfer

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Water Surplus Basins of India

Water surplus basins in India are mainly located in regions receiving high rainfall and having large river systems. These basins generate excess runoff, especially during the monsoon season.

1. Ganga–Brahmaputra–Meghna Basin

- This is the **largest and most water-rich river basin system in India**.
- It receives heavy rainfall and has large catchment areas.
- Rivers such as **Ganga, Brahmaputra, and their tributaries** carry enormous quantities of water.
- Frequent floods in these regions indicate surplus water availability.
- The Brahmaputra basin, in particular, has substantial surplus flows that can be utilized for deficit regions

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2. East-Flowing Peninsular River Basins

- Major east-flowing rivers like **Mahanadi, Godavari, Krishna, and parts of the Cauvery basin** receive relatively higher rainfall.
- Among these, **Mahanadi and Godavari basins** are identified as surplus basins.
- These rivers drain into the Bay of Bengal and often experience floods during monsoon seasons due to excess water.

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3. Western Coastal River Basins

- Rivers along the **Western Ghats and western coastal belt** receive very high rainfall.
- Though these rivers are short in length, they carry significant volumes of water.
- These rivers drain only about **3% of India's land area but carry nearly 11% of the country's water resources**, making them surplus in nature

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Importance of Water Surplus Basins

- Excess water from surplus basins can be transferred to **water-deficit and drought-prone regions** through inter-basin water transfer projects.
- Helps in flood control by diverting excess monsoon flows.
- Supports national water security, irrigation expansion, hydropower generation, and regional balance.

8. **Explain the Steps in Equitable Distribution of Water**

(10 Marks – VTU Answer Format)

Introduction

Equitable distribution of water refers to the **fair, just, and合理 allocation of available water resources** among different regions, sectors, and communities so that every section of society receives adequate water to meet its needs. In a country like India, where water

availability is uneven in time and space, equitable distribution is essential to reduce regional imbalances, conflicts, and socio-economic disparities

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Steps in Equitable Distribution of Water

1. **Assessment of Water Availability**
    - A detailed assessment of surface water and groundwater resources at river basin and regional levels should be carried out.
    - Identification of **water surplus and water deficit basins** helps in planning balanced distribution.
2. **Assessment of Water Demand**
    - Water demand for different sectors such as **domestic, agricultural, industrial, and ecological needs** should be properly estimated.
    - Priority should be given to drinking water and basic human needs.
3. **River Basin–Based Planning**
    - Water resources should be planned and managed on a **river basin approach** rather than administrative boundaries.
    - This ensures scientific and holistic allocation of water within the basin.
4. **Inter-Basin Water Transfer**
    - Transfer of water from **surplus basins to deficit basins** through canals and reservoirs helps achieve regional balance.
    - Interlinking of rivers is an important step toward equitable distribution.
5. **Construction of Storage Structures**
    - Construction of **dams, reservoirs, tanks, and check dams** helps store excess monsoon runoff.
    - Stored water can be supplied to water-scarce areas during dry seasons.
6. **Conjunctive Use of Surface and Groundwater**

- Simultaneous use of surface water and groundwater reduces stress on a single source.
- This helps in maintaining groundwater levels and ensures reliable supply.

7. **Efficient Water Allocation Policies**
   - Formulation of clear water allocation policies among states, regions, and sectors.
   - Legal and institutional mechanisms help resolve disputes and ensure fair sharing.
8. **Improvement in Distribution Infrastructure**
   - Development and maintenance of canals, pipelines, and distribution networks to reduce losses.
   - Minimizing leakage and conveyance losses improves availability.
9. **Demand Management and Conservation**
   - Promoting water conservation practices such as efficient irrigation, rainwater harvesting, and reuse of treated wastewater.
   - Reduced wastage leads to better availability for equitable distribution.
10. **Public Participation and Awareness**
    - Involving local communities and stakeholders in water management.
    - Awareness programs encourage responsible and equitable water use.

9. **Explain briefly Inter-Basin Water Transfer (IBWT)**

(10 Marks – VTU Answer Format)

Introduction

Inter-Basin Water Transfer (IBWT) is an important water resource management strategy adopted to address the problem of uneven distribution of water. In countries like India, where some river basins receive excess rainfall and experience floods while others face

chronic droughts, IBWT helps in achieving regional balance by transferring water from surplus basins to deficit basins

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Inter-Basin Water Transfer (IBWT)

Inter-Basin Water Transfer refers to the **planned transfer of water from a river basin having surplus water to another basin facing water deficit**, after meeting the existing and future needs of the donor basin. The main objective of IBWT is to ensure **uniform and equitable distribution of water resources** and to mitigate hydrological extremes such as floods and droughts.

Need for IBWT in India

- India has **highly uneven rainfall distribution** due to monsoonal climate.
- Floods frequently occur in the **northern and north-eastern regions**, while droughts affect central and southern regions.
- Increasing demand for water due to population growth, agriculture, industry, and urbanization.
- Large expenditure by the government every year on flood and drought relief measures.

Objectives of IBWT

1. To utilize surplus water effectively and economically.
2. To transfer water from surplus basins to deficit basins.
3. To mitigate floods and droughts.
4. To enhance irrigation potential and food production.
5. To support domestic, industrial, and power generation needs.

Examples of Inter-Basin Water Transfer Projects in India

- **Periyar – Vaigai Project**
- **Parambikulam – Aliyar Project**
- **Beas – Sutlej Link**
- **Indira Gandhi Canal Project (Rajasthan Canal)**
- **Kurnool – Cuddapah Canal**
- **Ramganga – Ganga Link**

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Advantages of IBWT

- Provides reliable water supply to drought-prone areas.
- Enhances irrigation and agricultural productivity.
- Reduces flood damage in surplus regions.
- Promotes regional socio-economic development.
- Reduces over-exploitation of groundwater.

10. **Explain the Objectives and Issues of Interlinking of Rivers**

(10 Marks – VTU Answer Format)

Introduction

Interlinking of rivers is a major water resource development strategy aimed at transferring water from water-surplus river basins to water-deficit basins. In India, due to uneven rainfall distribution and frequent occurrence of floods and droughts, the concept of interlinking rivers has gained importance to achieve equitable distribution of water and sustainable development

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Objectives of Interlinking of Rivers

1. **Equitable Distribution of Water**
    - To transfer surplus water from water-rich basins to water-scarce regions.
    - Ensures balanced regional development.
2. **Mitigation of Floods and Droughts**
    - Reduces flood intensity in surplus basins and drought severity in deficit basins.
3. **Enhancement of Irrigation Potential**
    - Provides additional irrigation to rain-fed and drought-prone agricultural areas.
    - Increases crop productivity and food security.
4. **Hydropower Generation**
    - Enables generation of hydroelectric power through multipurpose projects.
5. **Domestic and Industrial Water Supply**
    - Meets the growing water demand of urban, rural, and industrial sectors.
6. **Inland Navigation**
    - Facilitates inland water transport, reducing pressure on road and rail networks.
7. **Groundwater Recharge**
    - Improves groundwater levels through increased surface water availability.
8. **Socio-Economic Development**
    - Generates employment and promotes regional economic growth.

Issues (Problems) of Interlinking of Rivers

1. **Submergence of Land**

- Large areas may be submerged due to construction of dams, reservoirs, and canals.

2. **Environmental and Ecological Impacts**
    - Disturbs natural river ecosystems, biodiversity, and aquatic life.
3. **Inter-State and International Disputes**
    - Sharing of river waters often leads to political and legal conflicts.
4. **High Cost of Projects**
    - Construction and maintenance costs are very high, making projects economically challenging.
5. **Rehabilitation and Resettlement Problems**
    - Displacement of people due to land acquisition creates social issues.
6. **Water Losses and Pollution**
    - Water losses through seepage and evaporation in canals.
    - Risk of pollution during conveyance.
7. **Soil Erosion and Sedimentation**
    - Construction activities may increase soil erosion and sediment deposition.
8. **Technical Challenges**
    - Pumping water to higher elevations requires large energy input and maintenance.
9. **Long Gestation Period**
    - These projects are long-term and involve uncertainty in cost and benefit estimates.
10. **Public Acceptance**
    - Requires extensive debate and consensus at local, state, and national levels.

11. **Explain the Characteristics and Importance of Ground Water**

(10 Marks – VTU Answer Format)

Introduction

Ground water is one of the most important natural water resources and forms a major source of water for drinking, irrigation, and industrial purposes. It is the water that seeps into the soil and rocks and is stored below the Earth's surface in geological formations called aquifers. In India, ground water plays a vital role in sustaining water supply, especially during dry seasons and drought conditions

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Characteristics of Ground Water

1. **Occurs Below the Earth's Surface**
    - Ground water is found beneath the land surface in the **saturated zone** of soil and rocks.
    - The upper level of this zone is called the **water table**.
2. **Stored in Aquifers**
    - Aquifers are geological formations such as **sand, gravel, sandstone, limestone, and fractured rocks** that store and transmit ground water.
    - These formations are permeable and allow water movement.
3. **Slow Movement**
    - Ground water moves very slowly through pore spaces and fractures in rocks compared to surface water.
    - Due to slow movement, recharge and replenishment are gradual processes.
4. **Recharge Through Infiltration**
    - Ground water is recharged mainly by **rainfall infiltration** and seepage from surface water bodies.
    - Recharge depends on soil type, vegetation cover, and rainfall intensity.
5. **Fluctuating Water Table**

- The level of ground water rises during heavy rainfall and falls during continuous extraction.
- Over-exploitation causes long-term decline in water table levels.

6. **Generally Good Quality**
    - Ground water is naturally filtered as it passes through soil and rock layers.
    - However, it may contain dissolved minerals and can be contaminated due to natural or human activities.

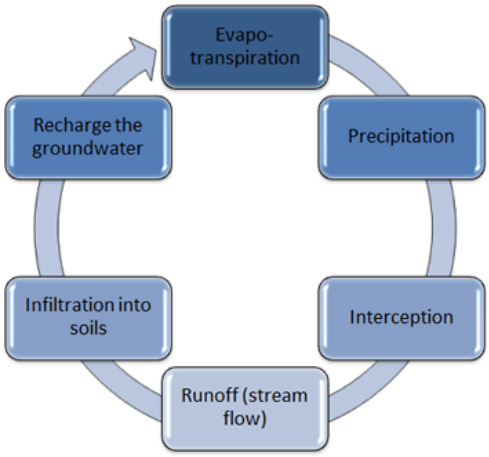
Importance of Ground Water

1. **Major Source of Drinking Water**
    - Ground water supplies drinking water to a large part of rural and urban population.
    - It is especially important in areas lacking reliable surface water sources.
2. **Support to Agriculture**
    - Ground water is extensively used for irrigation through wells and bore wells.
    - It ensures crop production during dry periods and monsoon failure.
3. **Reliable and Perennial Source**
    - Unlike rivers and reservoirs, ground water is less affected by seasonal variations.
    - It provides a dependable supply throughout the year.
4. **Drought Buffer**
    - During droughts, ground water acts as a critical buffer when surface water sources dry up.
5. **Industrial Use**
    - Many industries depend on ground water for processing, cooling, and cleaning operations.
6. **Supports Ecosystems**

- Ground water contributes to base flow in rivers and maintains wetlands and springs.
- It helps sustain ecological balance during dry seasons.

7. **Less Evaporation Loss**
    - Since it is stored underground, evaporation losses are negligible compared to surface water.

12. Explain Hydrological Cycle with Flowchart



Hydrological Cycle

The hydrological cycle describes the **movement, distribution, and storage of water** in different forms—liquid, vapor, and ice—across various components of the Earth system. It links surface water and groundwater and plays a crucial role in climate regulation, weather patterns, and water resource availability.

Processes Involved in the Hydrological Cycle

1. **Evaporation**
    - Solar heat causes water from oceans, rivers, lakes, reservoirs, and soil to evaporate and change into water vapour.

- Plants also release water vapour through **transpiration**.

2. **Condensation**
    - Water vapour rises, cools, and condenses to form clouds and tiny water droplets in the atmosphere.
3. **Precipitation**
    - When condensed water droplets become heavy, they fall to the Earth as **rain, snow, sleet, or hail**.
4. **Interception**
    - A part of precipitation is intercepted by vegetation and structures before reaching the ground.
5. **Infiltration**
    - Some portion of precipitation infiltrates into the soil and percolates downward to recharge **groundwater aquifers**.
6. **Surface Runoff**
    - Excess water that cannot infiltrate flows over land as runoff and collects in streams, rivers, lakes, and oceans.
7. **Groundwater Flow**
    - Infiltrated water moves slowly through aquifers and may re-emerge as springs or contribute to river flow.
8. **Storage**
    - Water is stored temporarily in oceans, glaciers, rivers, lakes, soil moisture, and groundwater.

13. Explain briefly the Conjunctive Use of Ground Water along with its Benefits

onjunctive Use of Ground Water

Conjunctive use of ground water is defined as the **simultaneous and judicious use of surface water (rivers, canals, reservoirs) and ground water (wells, bore wells)** in an integrated way so as to optimize the overall availability of water resources. It helps in

maintaining a balance between water withdrawal and recharge of aquifers and ensures long-term sustainability of water supplies

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Need for Conjunctive Use

- Uneven distribution of surface water resources.
- Seasonal variability of rainfall and river flows.
- Over-exploitation of ground water in many regions.
- Waterlogging and salinity problems in canal-irrigated areas.

Benefits of Conjunctive Use of Ground Water

1. **Prevents Over-Exploitation of Ground Water**
    - Reduces excessive pumping by supplementing ground water with surface water.
    - Helps maintain groundwater levels.
2. **Improves Ground Water Recharge**
    - Seepage from canals, tanks, and irrigated fields enhances recharge of aquifers.
3. **Reduces Waterlogging and Salinity**
    - Pumping of ground water in canal-irrigated areas lowers the water table.
    - Prevents soil salinity and waterlogging problems.
4. **Ensures Reliable Water Supply**
    - Provides a dependable supply during dry seasons or canal closures.
    - Acts as a buffer during droughts.
5. **Enhances Irrigation Efficiency**
    - Enables timely and controlled water application to crops.

- Improves agricultural productivity.

6. **Optimal Utilization of Water Resources**
    - Maximizes use of available surface and ground water without wastage.
    - Balances demand and supply efficiently.
7. **Improves Water Quality**
    - Mixing of surface water with ground water can reduce salinity and improve quality.
8. **Supports Sustainable Water Management**
    - Helps in long-term conservation and sustainable development of water resources.

14. Explain the Different Methods of Groundwater Recharge

Groundwater Recharge

Groundwater recharge is the process by which **water infiltrates into the soil and percolates down to replenish aquifers**. Recharge may be:

- **Natural recharge** – through rainfall, rivers, and lakes
- **Artificial recharge** – human-induced methods to enhance groundwater storage

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Methods of Groundwater Recharge

1. Natural Recharge

- Occurs through **rainfall infiltration**, seepage from rivers, lakes, and ponds.
- Depends on soil type, vegetation cover, rainfall intensity, and land use.
- This process is slow and often inadequate in drought-prone and urban areas

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2. Artificial Recharge Methods

Artificial recharge aims to supplement natural recharge by planned human activities.

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a) Percolation Tanks

- Shallow reservoirs constructed across streams or depressions.
- Store surface runoff and allow water to percolate into the ground.
- Widely used in hard-rock regions.

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b) Check Dams / Nala Bunds

- Small barriers constructed across streams and nalas.
- Reduce flow velocity and increase infiltration time.
- Effective in semi-arid and drought-prone regions.

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c) Recharge Wells

- Wells constructed to directly inject surface water into aquifers.
- Useful where surface soil layers are impermeable.
- Helps recharge deeper aquifers efficiently.

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d) Recharge Pits and Trenches

- Shallow pits or trenches filled with gravel, sand, and boulders.
- Collect rainwater and allow it to seep into the ground.
- Commonly used in urban areas.

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e) Infiltration Galleries

- Horizontal underground structures built near rivers.
- Collect water and allow slow infiltration into aquifers.
- Also used for water supply.

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f) Spreading Methods

- Spreading basins, flooding of fields, and irrigation canals.
- Large surface area allows gradual infiltration.
- Effective where soil permeability is high.

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g) Roof Top Rainwater Harvesting

- Rainwater collected from rooftops is directed to recharge pits or wells.
- Particularly useful in urban and residential areas.

Importance of Groundwater Recharge

- Arrests decline of groundwater levels.
- Improves groundwater availability during dry seasons.
- Prevents saline water ingress in coastal areas.
- Enhances sustainability of groundwater resources.
- Reduces dependence on surface water sources.

15. Explain Groundwater Contaminants and its Impact

Groundwater Contaminants

Groundwater contaminants are **undesirable physical, chemical, or biological substances** present in groundwater in concentrations higher than permissible limits. These contaminants may be **geogenic (natural)** or **anthropogenic (human-induced)**.

Types of Groundwater Contaminants

1. Geogenic (Natural) Contaminants

These originate from rocks and soil through natural processes.

- **Fluoride**

    - Common in many parts of India.
    - Excess fluoride causes dental and skeletal fluorosis.
- **Arsenic**
    - Found in sedimentary aquifers.
    - Highly toxic and carcinogenic.
- **Iron**
    - Causes discoloration, bad taste, and staining of utensils and clothes.

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2. Anthropogenic (Human-Induced) Contaminants

These result from human activities.

- **Nitrates**
    - Enter groundwater due to excessive use of fertilizers and sewage leakage.
    - High nitrate levels cause health problems, especially in infants.
- **Heavy Metals**
    - Include lead, mercury, chromium, and cadmium.
    - Released from industrial effluents and waste disposal.
- **Biological Contaminants**
    - Bacteria and pathogens from septic tanks and untreated sewage.
- **Chemical Pollutants**
    - Pesticides, phosphates, and hydrocarbons from agriculture and industries.

According to studies, nearly **60% of districts in India** face problems related to groundwater availability or quality or both

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Impact of Groundwater Contaminants

1. Impact on Human Health

- Fluoride causes dental and skeletal fluorosis.
- Arsenic leads to skin lesions, organ damage, and cancer.
- Nitrates cause “blue baby syndrome” and digestive disorders.
- Heavy metals damage the nervous system, kidneys, and liver.

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2. Impact on Agriculture

- Contaminated groundwater used for irrigation affects crop yield and quality.
- Accumulation of toxic elements in soil reduces soil fertility.

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3. Impact on Environment

- Polluted groundwater affects springs, wetlands, and river base flows.
- Disturbs ecological balance and aquatic life.

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4. Economic and Social Impact

- Increased cost of water treatment and healthcare.
- Loss of agricultural productivity.
- Reduced availability of safe drinking water leading to migration.

Preventive and Control Measures

- Proper treatment of industrial effluents and sewage.
- Controlled use of fertilizers and pesticides.
- Protection of groundwater recharge zones.
- Regular monitoring of groundwater quality.
- Artificial recharge and rainwater harvesting.
- Public awareness and strict enforcement of environmental regulations.