Key Conceptual Points to Memorize/Understand Thoroughly:

I. Effects of Urbanization

- **(a) On Flood Hydrology / Surface Hydrology:**
    - **Increased Impervious Surfaces:** (Roofs, roads, concrete) This is the primary driver.
    - **Reduced Infiltration:** Less water soaks into the ground.
    - **Increased Surface Runoff Volume:** More of the rainfall becomes immediate runoff.
    - **Increased Runoff Velocity:** Water flows faster over smooth, impervious surfaces and in engineered channels (drains, sewers).
    - **"Flashier" Hydrographs:**
        - **Shorter Time to Peak (Reduced Lag Time):** Water reaches rivers/outlets much faster.
        - **Higher Peak Discharge:** Greater volume and faster arrival combine to create larger flood peaks.
        - **Steeper Rising & Falling Limbs.**
    - **Reduced Baseflow:** Less infiltration leads to less groundwater recharge, which in turn reduces the sustained low flow (baseflow) in rivers during dry periods.
    - **Increased Frequency of Flooding:** Smaller rainfall events that might have been absorbed by natural catchments can now cause flooding due to rapid runoff.
    - **Overwhelmed Drainage Systems:** Existing natural or engineered drainage often cannot cope with the increased volume and speed of runoff.
    - **Altered Channel Morphology:** Higher peak flows can lead to increased erosion and channel instability in receiving watercourses.
- **(b) On Groundwater Hydrology:**
    - **Generally Reduced Recharge:** Less infiltration over large paved/built-up areas.
    - **Potentially Increased Localized Recharge (Anomalies):**

        - Leaking water mains and sewers can be significant sources of artificial recharge.
        - Soakaways and some Sustainable Drainage Systems (SuDS) are designed to promote local infiltration.
    - **Altered Groundwater Flow Paths:** Construction of deep foundations, tunnels, and basements can act as barriers or conduits, changing natural flow directions.
    - **Groundwater Level Changes:** Can lead to lowering of the water table due to reduced recharge, OR rising water tables in areas with reduced abstraction or increased leakage (sometimes causing groundwater flooding in basements).
    - **Groundwater Quality Issues:** Increased risk of contamination from leaking sewers, industrial spills, road runoff infiltrating through pervious patches or via poor well construction.
- **(c) On Water Quality (Surface & Ground):**
    - **Increased Pollutant Load in Runoff:** Impervious surfaces accumulate pollutants (oil, grease, heavy metals, litter, bacteria, nutrients from fertilizers on lawns) which are washed off quickly during rain.
    - **Combined Sewer Overflows (CSOs):** In areas with combined sewers, heavy rainfall can exceed system capacity, leading to discharge of untreated sewage mixed with stormwater into rivers.
    - **Reduced Natural Filtration:** Less infiltration means less opportunity for soil to filter pollutants.
    - **Thermal Pollution:** Runoff from hot impervious surfaces (asphalt, dark roofs) can warm receiving waters. WWTP effluent can also be warmer.
- **(d) On Water Management:**
    - **Increased Water Demand:** Concentrated populations and industries.
    - **Need for Engineered Drainage:** To manage increased stormwater.
    - **Need for Flood Defenses:** To protect urban areas.
    - **Increased Importance of SuDS/LID:** To mitigate runoff impacts locally.

II. Effects of Deforestation / Land Use Change (from Forest to Agriculture/Grassland)

- **(a) On Flood Hydrology / Surface Hydrology:**

- **Reduced Interception:** Trees intercept more rainfall than grass or crops; their removal means more rain reaches the ground directly.
- **Reduced Evapotranspiration (ET):** Forests generally have higher ET rates than grassland or many crops due to deeper roots and larger leaf area. Reduced ET means more water is available for runoff or recharge.
- **Potentially Altered Infiltration:**
  - Forest soils often have high infiltration rates due to organic matter and root systems. Removal can lead to soil compaction (e.g., by machinery, livestock if converted to pasture) and **reduced infiltration**, thus increasing surface runoff.
  - However, some deep-rooted trees can also lower water tables; their removal *could* locally raise water tables and increase saturation-excess overland flow.
- **Increased Surface Runoff Volume & Peak Flows:** Generally, due to reduced interception, reduced ET, and often reduced infiltration.
- **Increased Soil Erosion & Sediment Yield:** Loss of protective tree cover and root binding leads to more soil being dislodged by rain and carried into rivers.
- **Reduced Baseflow (if infiltration decreases significantly):** Despite higher overall runoff, if infiltration to groundwater is severely hampered, baseflow might decrease over the long term.

- **(b) On Water Resources / Hydropower:**
  - **Increased Total Annual Water Yield (Runoff):** Often, the reduction in ET outweighs changes in infiltration, leading to more total water flowing out of the catchment annually. This can be positive for water supply or hydropower *volume*.
  - **Altered Flow Regime:** Runoff may become "flashier" with higher peaks and potentially lower dry season flows if baseflow is impacted. This can be negative for hydropower (needs consistent flow) and water supply reliability (needs storage).
  - **Increased Sedimentation in Reservoirs:** Due to increased soil erosion.

III. Climate Change Impacts (General Hydrological Trends)

- **Increased Temperature:**
  - Higher Evapotranspiration (ET) rates (if water is available).

    - Changes in snow vs. rain patterns (more rain, less snow at lower elevations).
    - Earlier snowmelt, potentially larger spring melt floods.
- **Changes in Precipitation Patterns:**
    - **General Intensification:** "Wet areas get wetter, dry areas get drier" is a common, though very broad, generalization.
    - **Increased Intensity of Extreme Rainfall Events:** Even if total annual rainfall doesn't change much, it may fall in shorter, more intense bursts, leading to more flash floods and surface runoff.
    - **Increased Frequency/Duration of Droughts:** In some regions.
    - **Shift in Seasonal Patterns:** Rainy seasons might start earlier/later or become shorter/longer.
- **Impacts on Water Resources:**
    - Reduced reliability of water supplies in some regions.
    - Increased stress on existing infrastructure.
    - Changes in groundwater recharge rates (can increase or decrease depending on rainfall changes and ET).
- **Impacts on Flood Risk:**
    - Increased frequency and/or magnitude of floods in many areas due to more intense rainfall and potentially wetter antecedent conditions.
- **Sea Level Rise (Coastal Areas):**
    - Increased coastal flooding risk.
    - Saline intrusion into coastal aquifers.

IV. Key Concepts & Definitions (Know these well)

- **Hydrological Cycle Components:** Precipitation, Evaporation, Transpiration, Interception, Infiltration, Percolation, Runoff (Overland Flow, Channel Flow), Groundwater Flow, Baseflow, Storage (Surface, Soil, Groundwater).
- **Catchment Water Balance:** $\Delta S = P - E - Q - R$ (and its simplifications). Runoff Ratio.
- **Soil Moisture:** Saturation, Field Capacity (FC), Wilting Point (WP), Total Available Water (TAW), Readily Available Water (RAW), Depletion Factor (p), Soil Moisture Deficit (SMD).

- **Evapotranspiration:** ET0 (Reference), ETp (Potential), ETa (Actual), Kc (Crop Coefficient), Ks (Water Stress Coefficient).
- **Groundwater:** Aquifer (Confined, Unconfined), Aquitard, Aquiclude, Water Table, Potentiometric Surface, Hydraulic Head ($h = z + \psi$), Hydraulic Gradient, Darcy's Law ($q = -Ki$), Hydraulic Conductivity (K), Transmissivity ($T = KH$), Storativity ($S = HSs$), Specific Yield (Sy), Effective Porosity (ne), Pore Water Velocity ($v = q/ne$).
- **Wells:** Radius of Influence (re), Drawdown (s), Well Loss, Formation Loss, Well Efficiency.
- **Flooding:** Unit Hydrograph (definition, principles: linearity & superposition, duration, depth), Net Rainfall, Losses (Φ-index, Proportional), Baseflow Separation, S-Curve, Shortcut Method, Flood Frequency Analysis (Return Period T, Probability $P=1/T$), Gumbel Distribution (Method of Moments: α, β), Peaks Over Threshold (POT) vs. Annual Maxima (AM), Flood Forecasting (Lead Time, Linear Transfer Function).
- **Water Management:** Virtual Water (Blue, Green, Grey), Water Footprint.

V. Common "Discuss" or "Explain" Question Types:

- **Sources of Error:** In precipitation measurement, stage-discharge relationships, pumping test analysis.
- **Assumptions:** Of Darcy's Law, Theis solution, Unit Hydrograph method, Dupuit assumptions.
- **Comparison of Methods:** E.g., Lab K vs. Field K, different flood frequency methods, empirical vs. conceptual models.
- **Limitations:** Of Unit Hydrograph, Darcy's Law etc.
- **Why certain phenomena occur:** E.g., Why is specific yield different from total porosity? Why does well loss occur?