Chapter two

2. Geology and Hydrology water

2.1. Geology is the science and study of the solid matter that constitute the Earth.

- Encompassing such things as rocks, soil, and gem-stones.
- geology studies the composition, structure, physical properties, history, and the processes that shape Earth's components.

Cont…

- **Hydrogeology** (*hydro-* meaning water, and *-geology* meaning the study of the Earth) is the part of hydrology that deals with the **occurrence, distribution** and **movement** of **groundwater** in the **soil and rocks** of the Earth's crust, (**commonly in aquifers**).

Cont...

- The term **geohydrology** is often used interchangeably, Some make the minor distinction between a hydrologist or engineer applying themselves to geology (geohydrology), and a geologist applying themselves to hydrology (hydrogeology).
- **Environmental geology**, like hydrogeology, is a multidisciplinary field of applied science and is closely related to engineering geology and somewhat related to environmental geography.

Cont…

- They all involve the study of the interaction of humans with the geologic environment including the biosphere, the lithosphere, the hydrosphere, and to some extent the atmosphere. It includes:
- *Managing geological and hydrogeological resources such as fossil fuels, minerals, water (surface and ground water), and land use.*

Cont…

- *Defining and mitigating exposure of natural hazards on humans.*
- *Managing industrial and domestic waste disposal and minimizing or eliminating effects of pollution,*
- *Performing associated activities, often involving litigation.*

Cont…

2.2. ***Hydrology*** is a branch of earth science that is concerned with the distribution and movement of water on and under earth surface.

- ***2.2.1. Branches of hydrology***
- **Chemical hydrology**: is the study of the chemical characteristics of water.
- **Ecohydrology**: is the study of interactions between organisms and the hydrologic cycle.
- **Hydrogeology**: is the study of the presence and movement of water in aquifers.

Cont…

- **Hydrometeorology**: is the study of the transfer of water and energy between land and water body surfaces and the lower atmosphere.
- **Isotope hydrology**: is the study of the isotopic signatures of water.
- **Surface hydrology**: is the study of hydrologic processes that operate at or near the Earth's surface.

Cont…

- The science of **hydrology is of great importance** in environmental technology for many reasons.Two extreme hydrologic conditions;

➢ ***Droughts*** (not enough water where needed) and

➢ ***Floods*** (too much water in the wrong place) are well known for the environmental problems they cause.

➢ However, droughts and floods are not the only aspects of hydrology that are important.

Cont…

- In general, the presence and quantity of water must be estimated in order
- ✓ to plan, design, and operate water supply projects
- ✓ To plan and design of hydro power projects
- ✓ To plan and design of irrigation projects
- ✓ pollution control, and storm management
- ✓ To plan and design of flood regulating structures.
- ✓ water management facilities. Therefore, hydrology is a science that provides basic information for the management of water resources within the framework of hydrology and hydrological economy.

Cont…

- The science of hydrology can be classified as *Hydrometeorology* and *Hydrography.*
- ***Hydrometeorology*** deals with rainfall and other forms of precipitation with the return of moisture to the atmosphere.
- ***Hydrography*** (*also called surface water hydrology)* deals with streams and runoffs.

Cont…

Hydrography can be divided in to:

a) ***Potomology:*** -deals with water flowing in brooks, and streams

b) ***Limnology :*** - deals with fresh water in ponds, Lakes, reservoirs.

c) ***Oceanology (marine science):*** **-** is the branch of Earth Sciences that studies the Earth's oceans and seas;also called *Oceanography.*

- ***What is ground water hydrology?***

Cont…

2.3. Geological of Water

- The three zones of earth corresponding to the three states of matter (solid, liquid and gas);these zones are:

1. ***Lithosphere*** **:-** Solid central zone
2. ***Hydrosphere*** **:-** The zone of water-cradled in the ocean basins and distributed across the surface of the land
3. ***Atmosphere*** **:-** Gaseous envelope surrounding them

Cont…

- The property of water that sinks in to the ground and its availability depends on the characteristics of geological formations;
- ✓ The outer most layers of the earth are largely composed of porous materials such as sand, silt and gravel and decaying vegetation.
- ✓ Underneath these layers are porous and decomposed rocks and,
- ✓ Beneath these are bedrocks so compact because of its molten origin.

Cont…

Groundwater is drawn from many geological formations

- ✓ i. **From the pores of the *alluvial*** *(water blown)* or *glacial (wind blown)* deposits of granular unconsolidated materials, such as *sand* and *gravel* and from consolidated materials such as ***sandstone.***
- ✓ **From solution passage.**
- ✓ **From rapture of fissures of igneous rocks.**
- ✓ **From combination of unconsolidated an consolidated geological formations.**

- Among these fractures of decomposing rock formations granite can yield a great amount of water.

Cont…

- *The process of decomposition is performed as follows:*
- a) Consolidated rock formations are broken by parallel system of cracks called joints.
- b) Water enters the joints (cracks) and gradually dissolve the rocks, so that it becomes decomposed;such rocks are permeable
- c) The amount of water may flush out from decomposed or weathered rocks there by enlarging the openings thus, such decomposed granite yields more water than any formation.

Cont….

2.4. Classification and characteristics of rock formations

According to their origin, geologists divide rocks in to three categories:

A. Igneous rocks: These rocks are produced by the cooling and solidification (hardening) of molten materials (magma).

- Magma, which reaches the surface, is called *lava.*

Cont…

- These rocks are formed underextremely high pressures and temperatures.

Example of such rocks are **granites, basalts** etc.

- From the point of view of prospecting for groundwater, these rocks are the least likely sources to furnish adequate water supplies.

Cont…

B. Sedimentary rocks**:** Rocks which are formed as the result of weathering (erosion, wearing away, denudation, deposition, etc) of the older igneous rocks.

- Some of the common agents of these changes are *heat, ice, wind, water,plants and animals.*
- Examples of sedimentary rocks are *alluvial deposits, limestone, sandstone, etc.*.

Cont…

- Such rocks are highly porous as a result, of which they allow water from the ground surface to infiltrate or percolate and at the same time hold it.
- From groundwater point of view, sedimentary rocks are the best or most likely formations for storing abundant supply of water.

Cont…

C. Metamorphic rocks: Rocks produced as the result of alteration of other rocks by heat and /or pressure.

- Examples of metamorphic rocks are *marble, slate, genesis, schist, etc.*
- Metamorphic rocks are generally poor reservoir rocks for storage of groundwater.

Cont…

2.5. Rock formations in relation to water bearing and water development

- **Aquifers:**
- An aquifer is a geologic unit (or layer) of permeable material (like sand, gravel or fractured bedrock) that is capable of providing usable quantities of water to a well.

  A quifers can **be*confined*** **or** ***unconfined.***
- A confined aquifer has a low permeability confining layer (an aquitard or aquaclude), such as clay, above and below which restricts the upward and downward movement of water from the aquifer.

Cont…

- Generally, the more productive and useful aquifers are in sedimentary geologic formations,
- though weathered and fractured crystalline rocks yield smaller volumes of groundwater in many environments. Among the most productive groundwater environments are unconsolidated to poorly cemented alluvial materials that have accumulated as valley-filling sediments in major river valleys and geologically subsiding structural basins.

Cont…

- The **amount of water** that can be **obtained from** a given **rock formation depends** up on a number of factors which include
- the ***thickness of the formation, its extent*** *and* ***its porosity****.* The **rate at** which water can be **extracted** depends up on **its permeability**.

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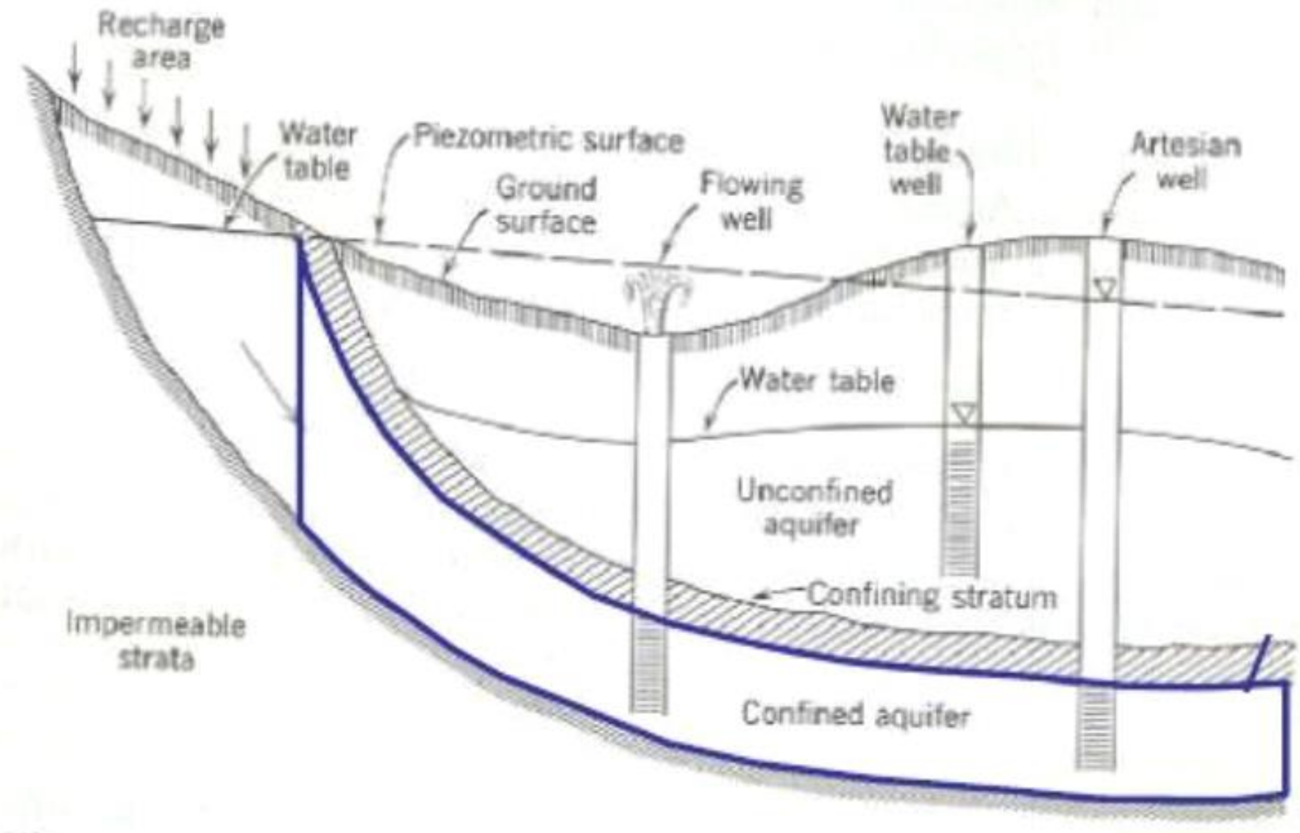

Groundwater hydrology, Todd, 1980

Figure 3.2 Confined and unconfined aquifer

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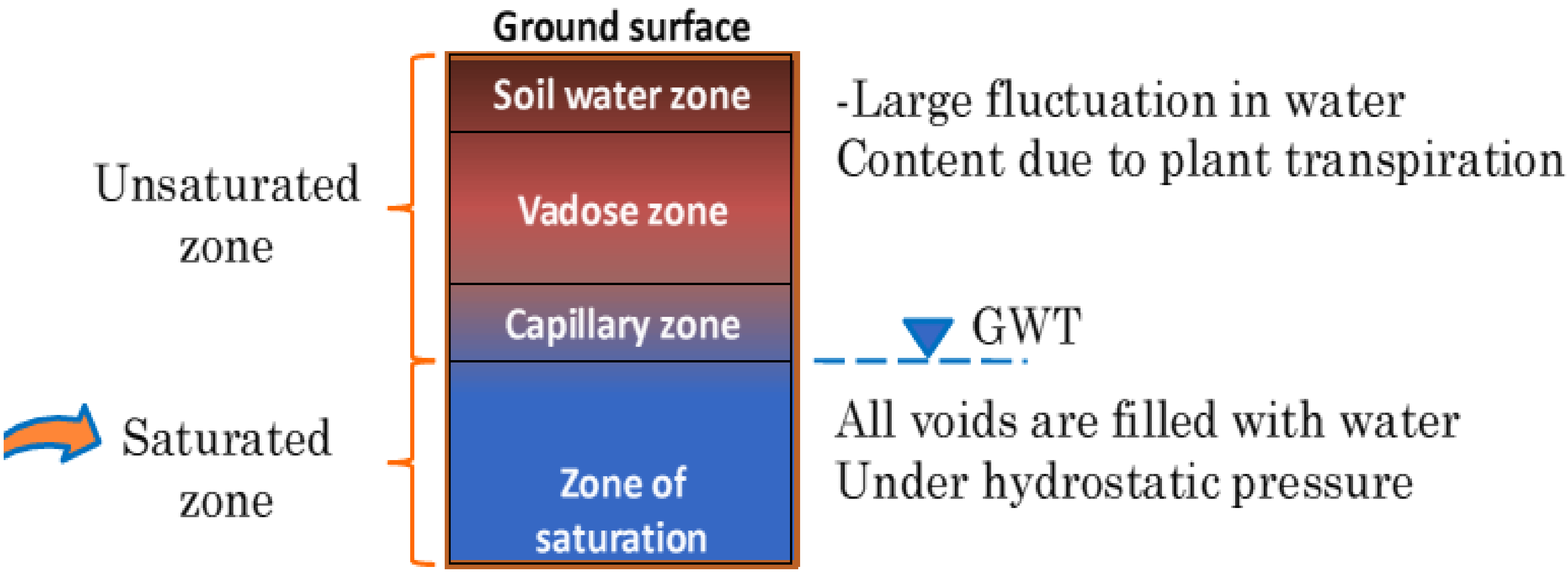

Aquifer is a water-bearing formation that is saturated and that transmits large quantities of water.

Cont...

AQUIFER PARAMETERS

- *Porosity*: ratio of volume of voids to total volume

$$n = \frac{Vt - Vs}{Vt}$$

  - Vt is total volume of soil and Vs is the volume of solids
- *Specific yield(Sy)*: amount of water that will drain under the influence of gravity

$$Sy = \frac{Vd}{Vt}$$

- *Specific retention(Sr):* part that is retained as a film on rock surfaces and in very small openings.

$$Sr = \frac{Vr}{Vt} \qquad n = Sy + Sr$$

Cont….

AQUIFER PARAMETERS

- *Storage coefficient (S):* the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head

$$S = \frac{\text{Volume of water}}{(\text{Unit area})(\text{unit head change})}$$

- *Hydraulic gradient (dh/dx):* the slope of the piezometric surface or water table line in m/m. The magnitude of the head determines the pressure on the groundwater to move and its velocity.

Cont...

AQUIFER PARAMETERS

- *Hydraulic conductivity(K):* ratio of velocity to hydraulic gradient, indicating permeability of porous media.

$$K = \frac{QdL}{Adh}$$

- *Transmissivity:* the capacity of an aquifer to transmit water
  - measure of how easily water in a confined aquifer can flow through the porous media.

$$T = Kb, \qquad b = \text{saturated thickness}$$

Cont…

- ***Porosity:***
- The porosity of a rock is determined by the amount of open spaces, voids, interstices or pore
- spaces between the particles that make up the formation.
- It is expressed as the ratio of the aggregate volume of interstices in a rock to its total volume.
- Naturally, the greater the amount of such interstices the greater the volume of water the rock can hold.

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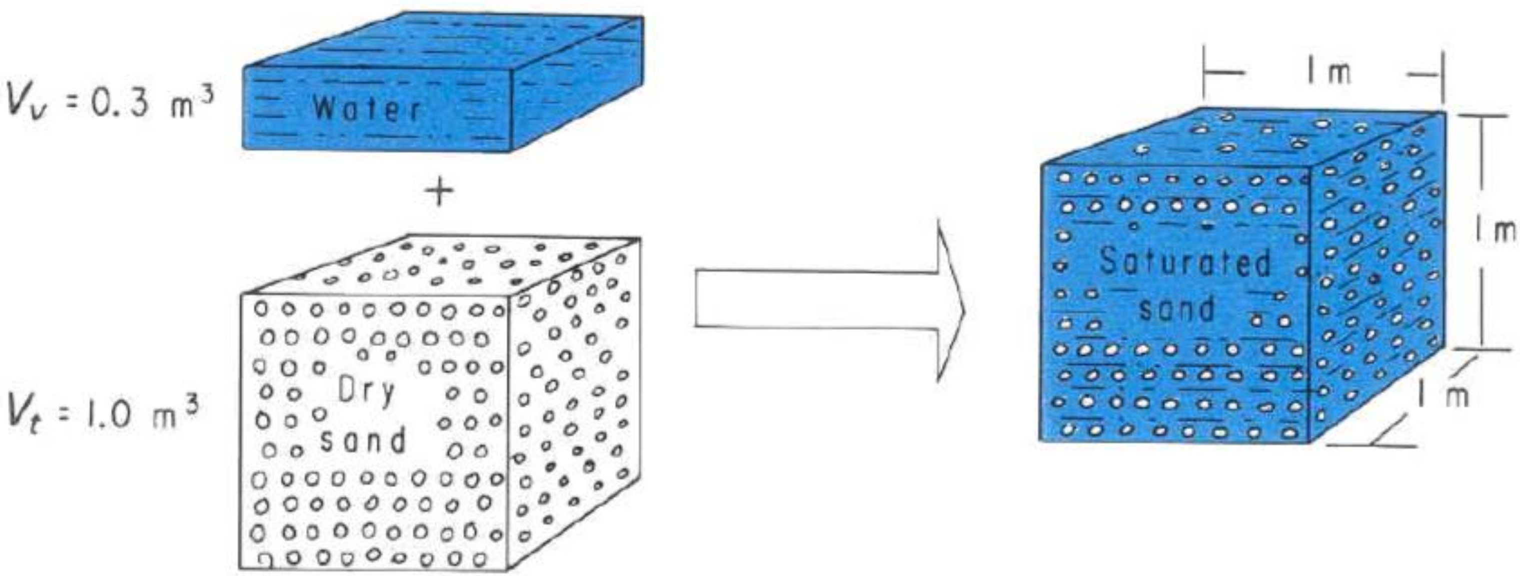

$$\text{Porosity } (n) = \frac{\text{Volume of voids } (V_v)}{\text{Total volume } (V_t)} = \frac{0.3\ m^3}{1.0\ m^3} = 0.30$$

Cont...

- **Porosity** varies with the type of rock that makes up the water-bearing stratum. Examples of porosity percentages of common rocks are depicted in the following table.

Cont...

Sr.No	Type of rocks	Porosity (%)	Grading pore space in rock
1	Top soil	37-65	Very high
2	Clay	44-47	Very high
3	Sand and gravel compacted	35-40	Very high
4	Chalk	14-45	High
5	Sand stone	4-30	High
6	Limestone	0.5-17	Fairly high
7	Granites, schist (igneous and metamorphic)	0.02-2	Very high

Cont…

Permeability

- Is the capacity or ability of the rock formation to transmit water under force whether gravity or otherwise. The opposite of permeability is impermeability.
- When rain falls on the surface of a rock formation it will percolate into the ground if the rock stratum is permeable, and will keep going down until it reaches an impermeable layer.
- Relating permeability to water bearing strata, we find that gravel and coarse sand have high permeability, while clay and topsoil generally have low permeability.

Cont…

Another effective ground water factor that has to be considered along with porosity and permeability of a rock formation is the ***specific yield*** of the rock formation.

- **Specific yield** may be defined as the **quantity of water** that a formation **will yield** in **proportion to the total amount it holds.**
- In other words, it is the difference between the absolute total amount the formation holds and the amount it can yield when tapped.

Cont…

- **For example**; if a **certain type of rock formation has a porosity of 20%** it will yield only **half of this water**, then the rock is said to have a **specific yield of 10%.**
- A specific yield of 10%, however, represents a great volume of available water in storage.
- Topsoil with 50% porosity will have yield of 25%.

Cont…

- Some portion of groundwater is held by the rock particles by means of molecular attraction and is not available. The property of retaining this amount of water is termed the ***specific retention of the rock formation.***

Water table: As the rainwater percolates through the ground, a certain portion of it may be absorbed by the roots of plants, and a certain portion may be held by the rock particles by means of capillary and molecular attraction.

Cont…

- The remaining portion travels down under the force of gravity until an impermeable formation stops it from further travel. At this point all the rock particles are saturated with water.
- Further percolation will form a sort of underground pool or river. The upper surface of this zone of saturation is called the ***Water table.***

Cont…

- underground water is not stationary, but will move laterally in the direction of the steeps downward slope. This direction of greatest slope in which groundwater flows is known as the ***Hydraulic gradient.***
- Of course, the hydraulic gradient alone will not make ground water move if the rock formation in its path is impermeable.

Cont...

- The water table of an area is not permanent. It fluctuates or changes with the amount of rainfall which feeds it, and so, during rainy seasons it is high, and during dry seasons it is low.
- This is why some wells decrease their yield, or even dry up during the driest months of the year.

Cont…

Natural hydrologic cycle

- The ultimate source of all our water supply is rainfall. The constant movement of water from clouds to earth and back again into the atmosphere powered with the energy from the sun and from gravity is known as the *hydrologic cycle* or *the water cycle.* As it is a natural phenomenon it can be said as the *natural hydrologic cycle.*

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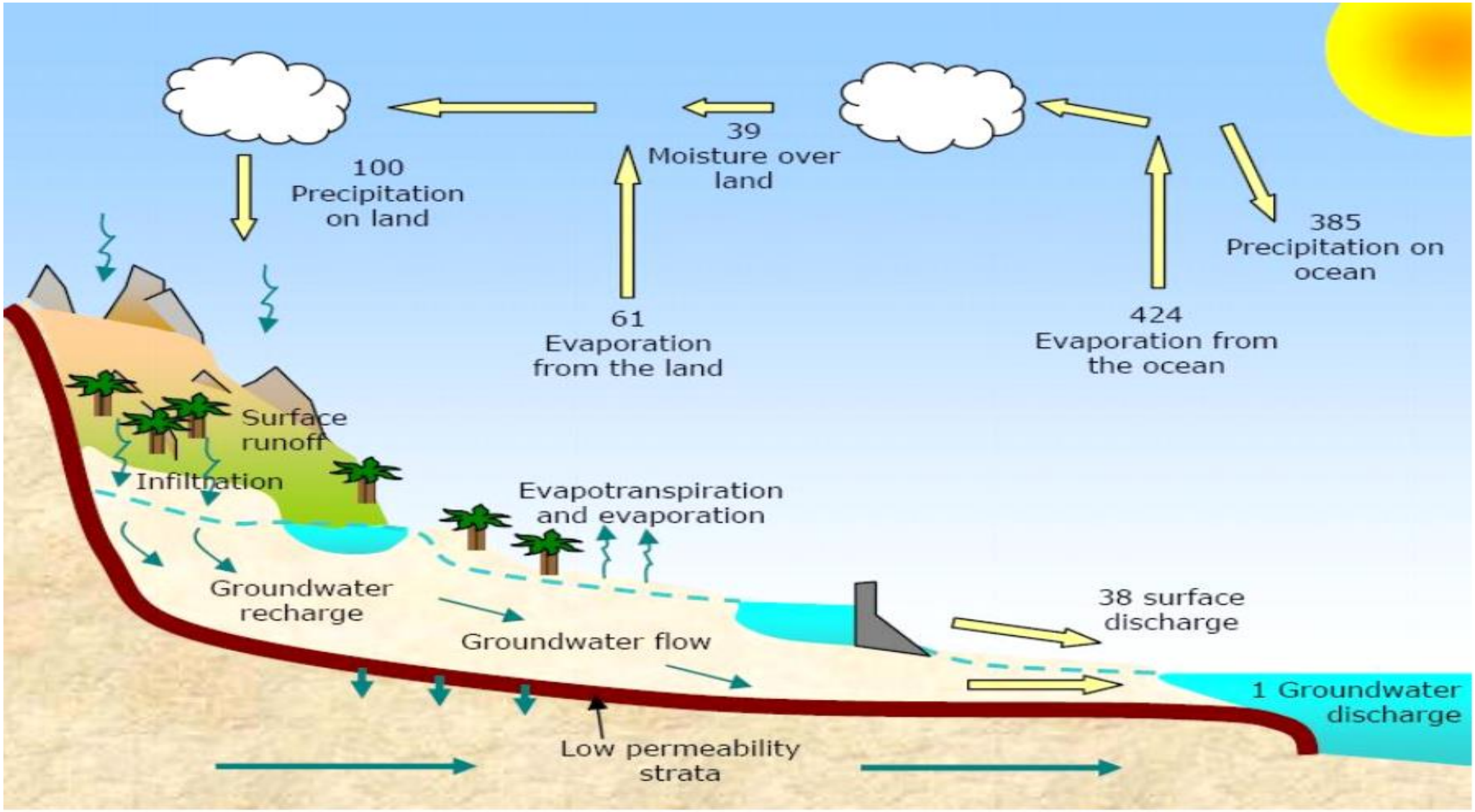

Hydrologic Cycle

Cont….

Urban hydrologic Cycle

- This description of the hydrologic cycle is a version of the natural hydrologic cycle, but in this case, human beings play a central role.
- A most significant aspect of environmental technology is the maintenance of this urban water cycle while protecting public health and environmental quality.

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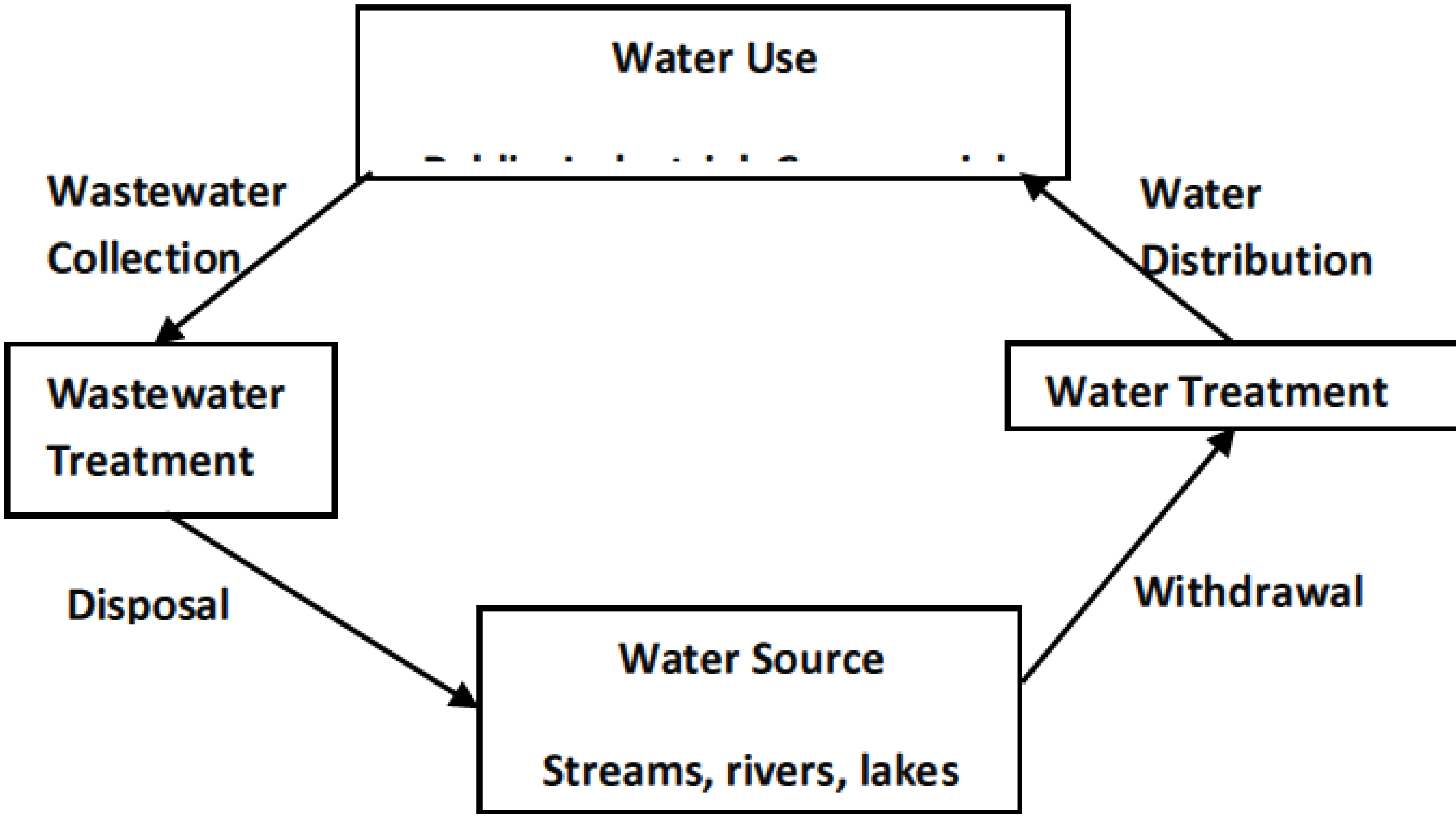

Figure 3.5 The urban hydrologic cycle