"TIIAME" NRU
"Tashkent Institute of Irrigation
& Agricultural Mechanization Engineers"
National Research University

Faculty of Hydromelioration
60530800 – Hydrology (by networks)
70530804 – Hydraulics and engineering hydrology specialty
Course on "Engineering groundwater"

Lecture #1: Subject of groundwater hydraulics and filtration in structures

Lecture Outline

1. Introdution
2. Occurrence and sources of underground water
3. Types of underground water according to the conditions of its occurrence
4. Types of aquifers
5. Interlayer groundwater
6. Movement of underground water

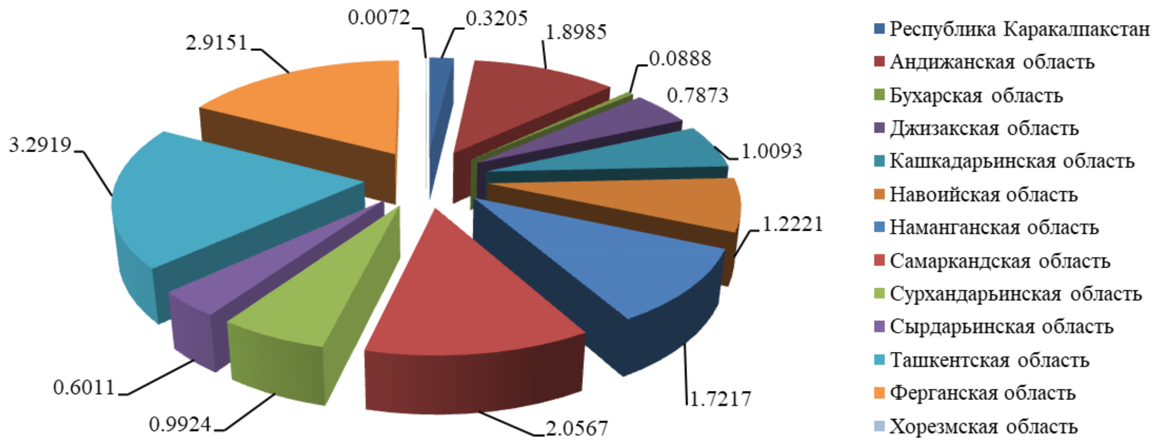
PhD Ruziyev I.M.

INTRODUCTION

- Accounting for approximately 99% of all liquid freshwater on Earth, groundwater has the potential to provide societies with tremendous social, economic and environmental benefits and opportunities. Groundwater already provides half of the volume of water withdrawn for domestic use by the global population, including the drinking water for the vast majority of the rural population who do not get their water delivered to them via public or private supply systems, and around 25% of all water withdrawn for irrigation. However, this natural resource is often poorly understood, and consequently undervalued, mismanaged and even abused.

- There are 97 underground water deposits on the territory of Uzbekistan. Stocks of fresh groundwater over the past five decades have decreased by 35% due to the intensive development of industry and agriculture (mainly unauthorized construction of water intake facilities and uncontrolled water withdrawal). Therefore, 19 deposits are classified as protected natural areas - zones of formation of deposits of fresh groundwater*.

- Monitoring of the state of groundwater is carried out at 1465 points. As of 01/01/2017, the natural resources of fresh and slightly brackish groundwater are 27.6 km^3 (874.8 m^3/s), approved reserves are 6.2 km^3 (195 m^3/s), of which total withdrawal is 2 .0 km^3 (63.4 m^3/s). About 70% of approved fresh groundwater reserves are concentrated in Tashkent (3.3 km^3), Ferghana (2.9 km^3), Samarkand (2.1 km^3) and Namangan (1.9 km^3) regions of the country.



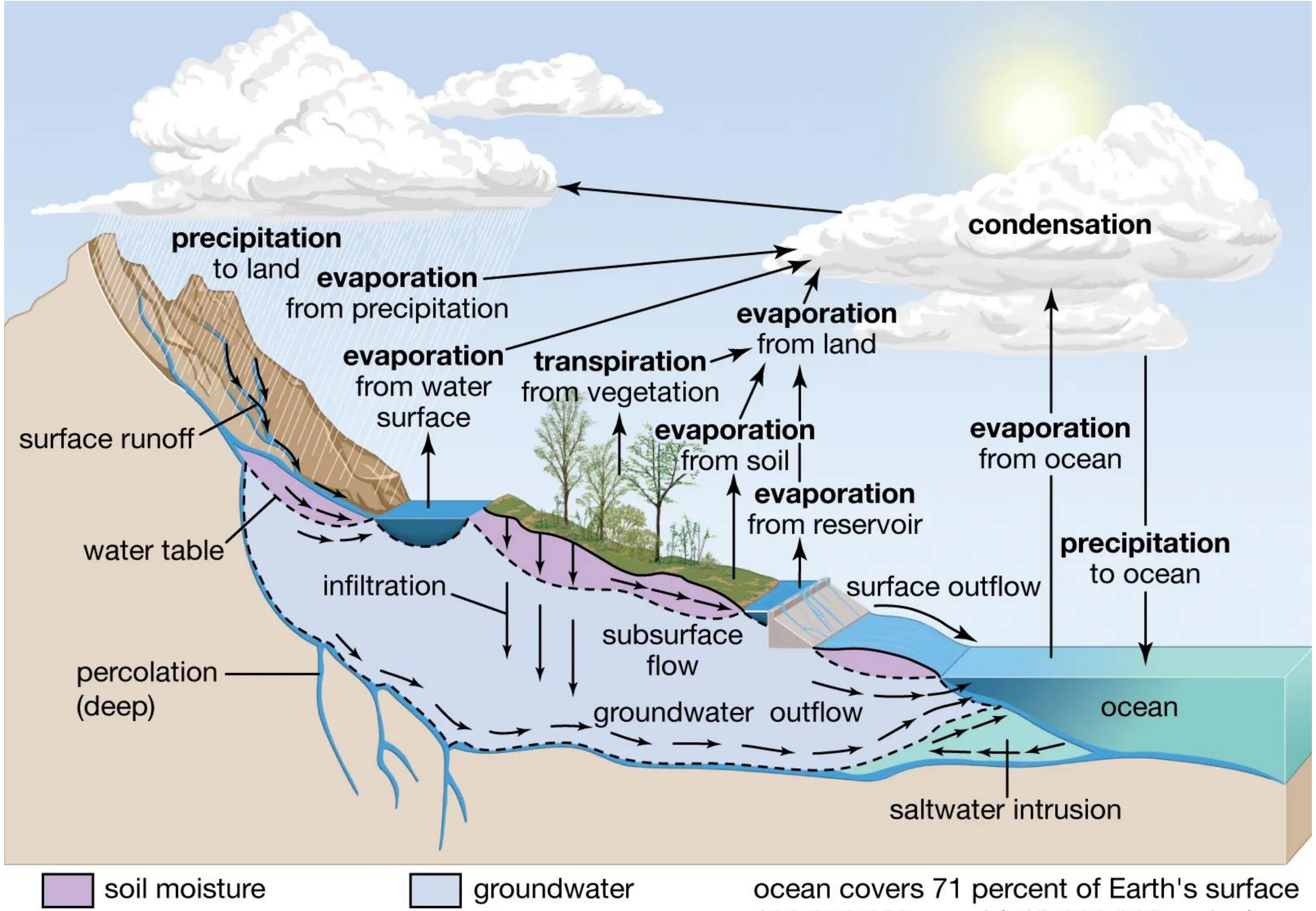
Source: Decree of the President of the RUz dated on 04/05/2017 № ПП-2954.

* www.gpniimr.uz/index.php?part=2&id

OCCURRENCE & SOURCE OF UNDERGROUND WATER

- Groundwater or phreatic water is subsurface water which absolutely saturates the pore spaces above an impermeable layer.

- Water found in the pore spaces, cracks, tubes, crevices beneath the surface has been termed as underground water, groundwater, subsurface water and subterranean water.



OCCURRENCE & SOURCE OF UNDERGROUND WATER

There are four sources of groundwater:

(i) Connate water: At the time of rock formation water is trapped in the interstices of sedimentary rocks.

(ii) Meteoric water: It originates in the atmosphere, falls as rain and ultimately becomes groundwater by infiltration. It forms the major part of groundwater.

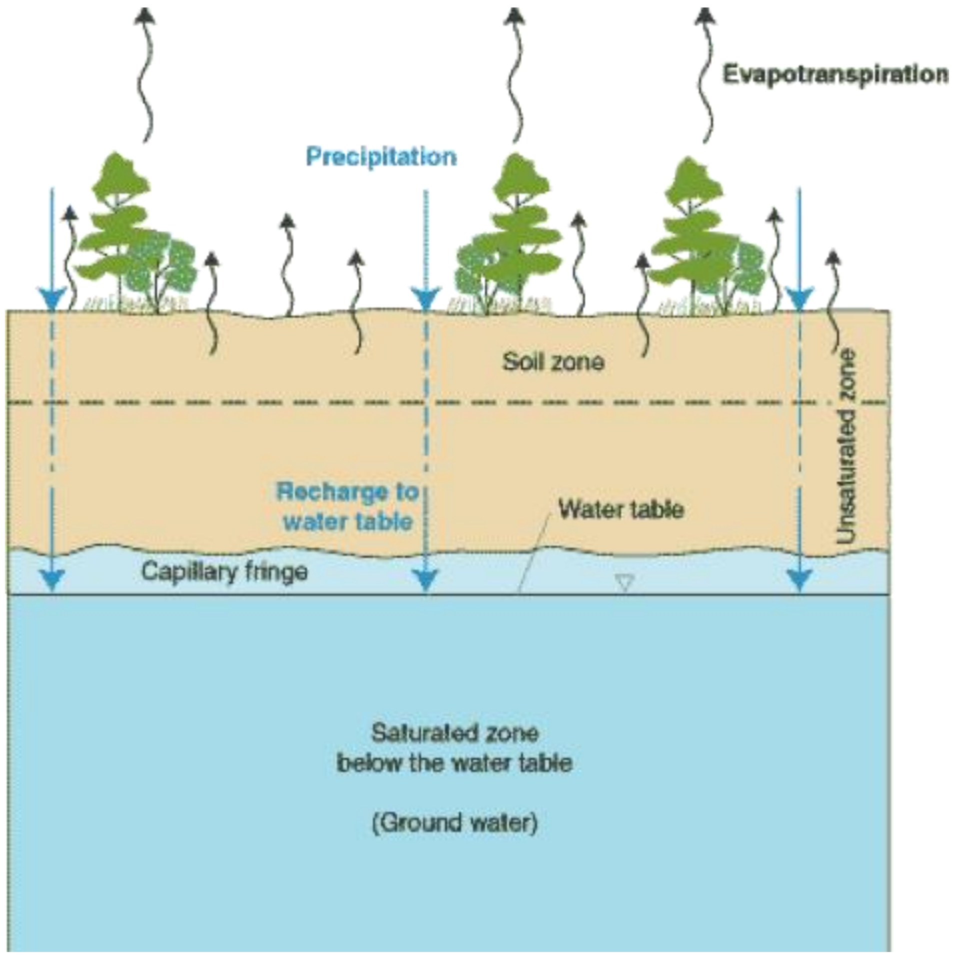
(iii) Juvenile water: It originates in the earth’s interior and reaches the upper layers of the earth’s surface as magmatic water.

(iv) Condensational water: It is the prime source which replenishes water in deserts and semi-desert areas. During summer, land becomes warmer than the air trapped in the soil, which leads to a huge difference of pressure between the water vapour in the atmosphere and the water vapour trapped in the soil. Thus the atmospheric water vapour penetrates the rocks and gets converted into water due to falling temperature of the water vapour below.

OCCURRENCE & SOURCE OF UNDERGROUND WATER

- In addition to atmospheric waters, there are deep waters in the earth's crust. More than half of all groundwater is available within 750 m of the earth's surface. They are formed from the fusion of oxygen and hydrogen, and are released from molten and slowly cooling rocks. The water formed by the absorption of atmospheric water into the ground is called percolating water.

- The more precipitation there is, the more it accumulates in the soil in the form of gravity water, begins to flow slowly and penetrates to a depth where evaporation is not possible. In this way, the place of underground water is always filled. Water below the ground is available in four zones, viz., soil zone, intermediate zone, capillary zone and saturation zone.

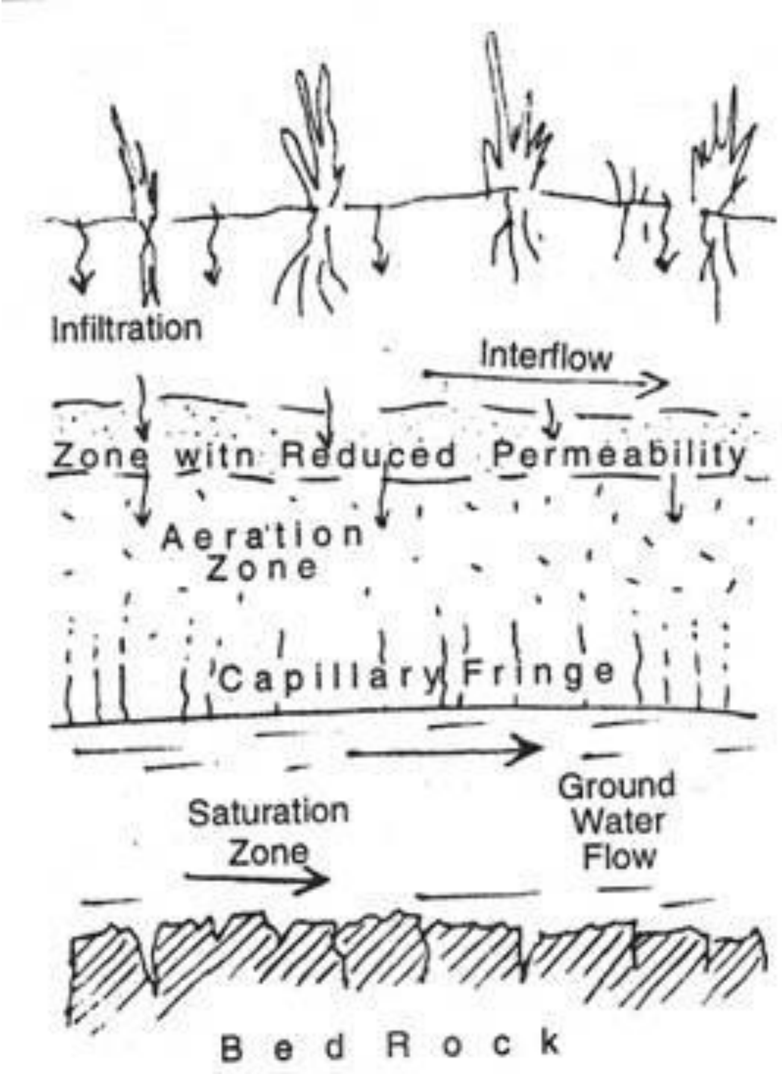


OCCURRENCE & SOURCE OF UNDERGROUND WATER

- The zone where water is available is called the zone of aeration. There are two forces which actively prevent groundwater from moving downward, viz., (a) the molecular attraction between water and the rock and earth materials and (b) the molecular attraction between water particles.

- The zone of aeration is further sub-divided into three layers—soil moisture zone, intermediate zone and capillary zone, collectively called Vadose Zone. Some amount of water in this zone is used by plants. At the bottom of the intermediate zone lies the capillary fringe (a thin layer of 2 to 3 cm) from where water moves upward. The capillary condition is temporarily destroyed when heavy rain takes place. In such cases the groundwater body is replenished by recharge.

- The zone of saturation lies below the zone of aeration and is also called the phreatic zone. The water available in this zone is known as groundwater. The groundwater table or water table segregates the zone of aeration and the zone of saturation. The maximum elevation of water in a well which penetrates the groundwater zone is known as piezometric water table. Generally, the water table follows the irregularities of the earth's surface; for example, the water table is highest beneath hills and lowest beneath valleys.



Groundwater zones

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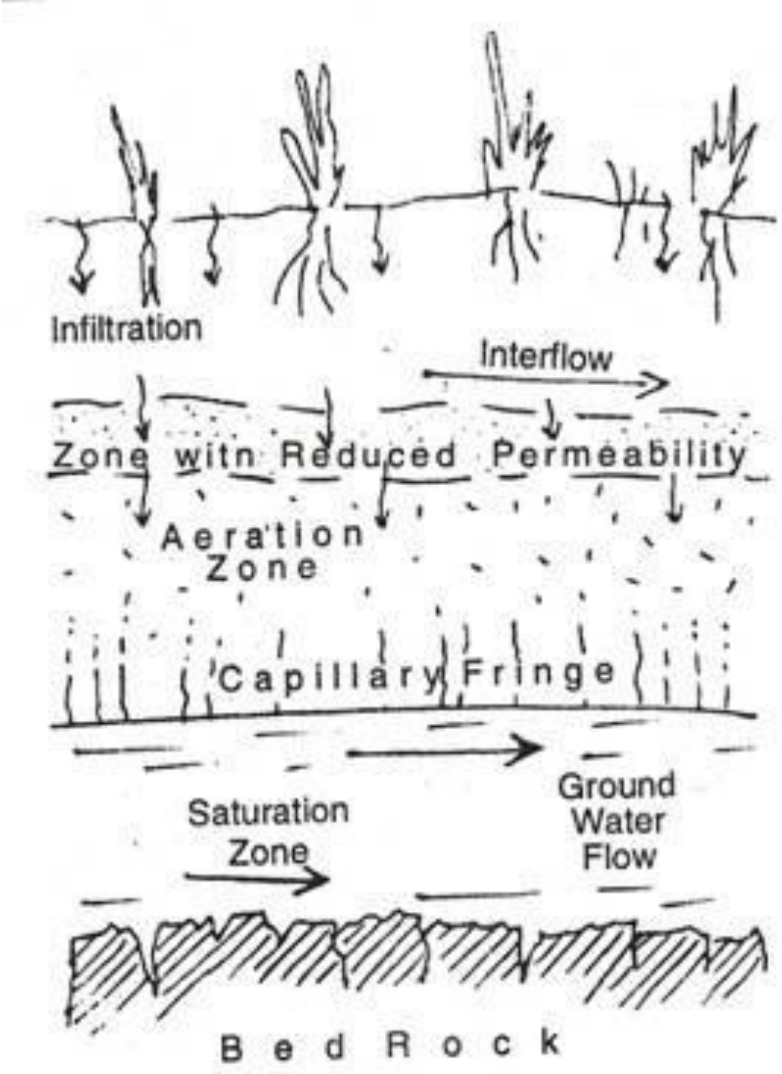


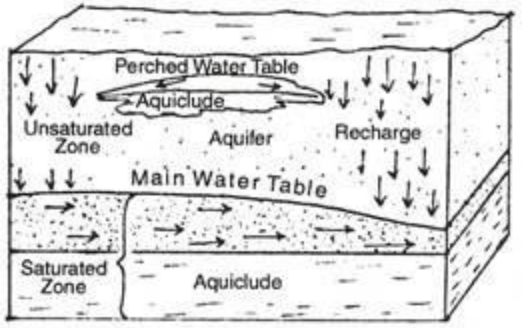
Groundwater zones

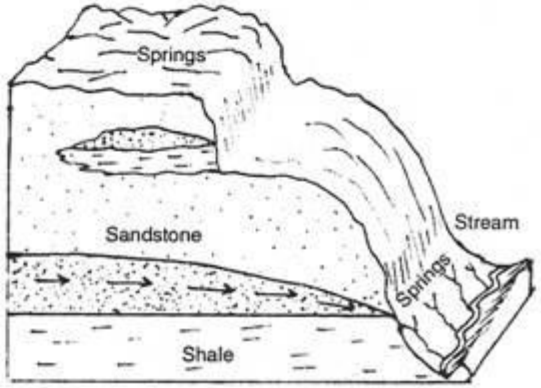
OCCURRENCE & SOURCE OF UNDERGROUND WATER

- A geological structure fully saturated by water, capable of producing sufficient quantities of water that can be economically used and developed, is known as aquifer (Latin; to bear water). Examples include sandstone layer, unconsolidated sand and gravel, limestone, fractured plutonic and metamorphic rocks which act as aquifers. An aquifer can be broadly divided into (a) unconfined and (b) confined aquifers.

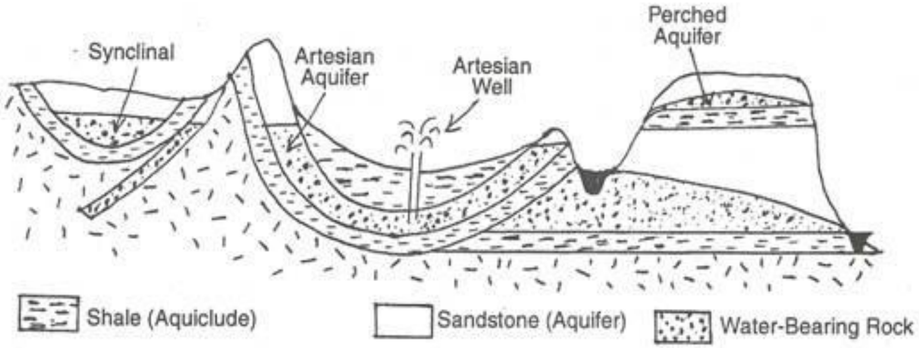
- In the former case, water recharge may take place from lateral groundwater flow or from upward movement of water. The latter (also known as artesian or pressure aquifers) have an impermeable stratum that maintains hydrostatic pressure sufficient enough to raise water higher than the surface of the aquifer. Confining layers of the aquifer can be categorised into aquicludes, aquitards and aquifuges. Aquicludes form small saturated layers above the impermeable layers; examples are clay, shale and most of the igneous and metamorphic rocks.

- Aquitards’ form confining layers but cannot completely check water flow to or from an adjacent aquifer. An aquifuge consists of a rock layer which has no interconnected opening or interstices. So it neither stores nor transmits water, for example, quartzite, obsidian. Water penetrates an aquifer through a recharge area which is exposed or is covered by a permeable zone of aeration. Water rises to the level of water table if digging can be done through the zone of aeration into the saturation zone.





Groundwater flow in hc ‘zontal rockstrata.



Various types of aquifers.

OCCURRENCE & SOURCE OF UNDERGROUND WATER

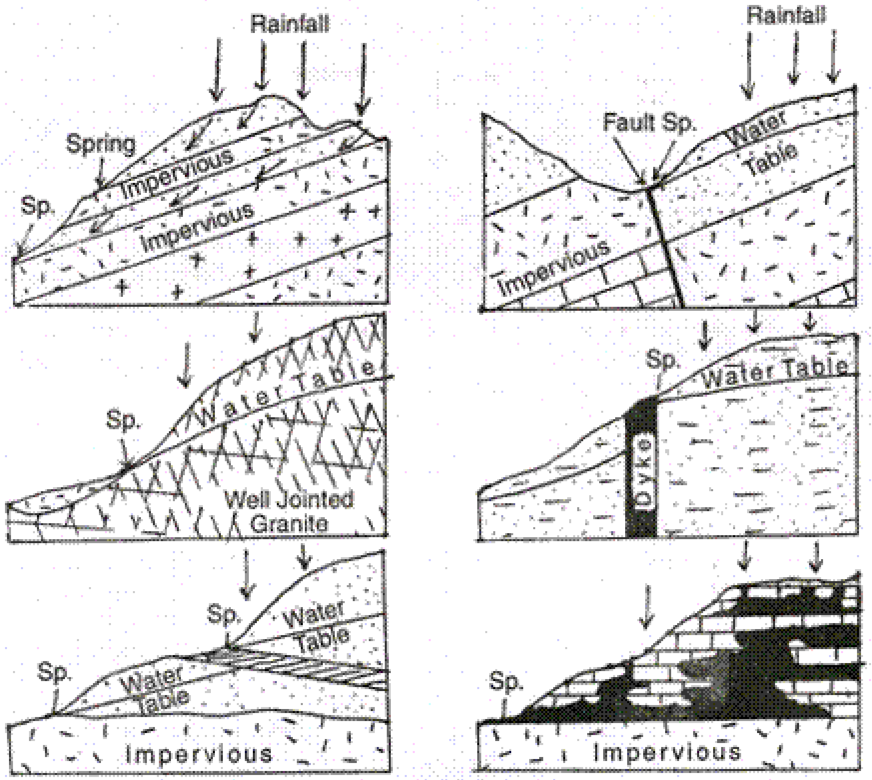
The occurrence of groundwater is influenced by the following factors:

- Climate Groundwater is easily available at great depths in arid regions while it exists at shallow depth in humid regions. Water table rises during rainy season and sinks in dry season.
- Topography the water table tends to be higher near the hilltops and lower near the valleys, because near the valleys water seepages into streams, swamps and lakes cause descending water table.
- Types of Materials Porosity and permeability of the underground materials have an impact on the storage and movement of groundwater. The variability in porosity exists as the underground materials are heterogeneous in nature.
- Porosity refers to the percentage of the total volume of rock with voids. Porosity determines the volume of water a rock body can retain. Four types of pore spaces are found—(i) Pore space between mineral grains, (ii) Fractures, (iii) Solution cavities, and (iv) Vesicles.
- Permeability refers to the capacity of a rock body to transmit water. Sandstone and conglomerate are highly permeable because of the presence of relatively large interconnected pore space between the grains.
- Nature and Movement of Groundwater The groundwater movement takes place through pore spaces at extremely slow velocity. The flow velocity of groundwater is expressed in $metres^{-1}$ day. Water percolates from areas of high water table to the areas where water table is lowest i.e., towards lakes and surface streams.
- Such differences of water table are known as hydraulic head. Groundwater percolates through the soil layers after being activated by gravity. Since the bottom layers of a soil are compact due to tremendous weight exerted by the overlying soil, permeability decreases downward. So, the vertical infiltration of water decreases and if the soil is situated on a slope groundwater deflects downslope as thorough flow.

OCCURRENCE & SOURCE OF UNDERGROUND WATER

The occurrence of groundwater is influenced by the following factors:

- The nature of groundwater at shallow depth reveals that it acts both as reservoir as well as conduit. Groundwater at shallow level forms a small but integral part of the hydrological cycle.
- Precipitation falls on recharge areas where water adds up to the saturated zone. It moves ultimately to discharge areas i.e., areas where subsurface water is discharged to river or other water bodies. The areal extent of discharge areas is smaller than recharge areas.
- In humid regions recharge areas are found everywhere except streams and adjacent floodplains whereas in arid regions recharge areas encompass only the mountains and bordering alluvial fans and also the major streams underlain by porous alluvium through which water percolates and recharges groundwater.
- The fluctuation of water table is evident from the fact that in regions like the Indian subcontinent which experiences monsoon climate, the water table flattens and gradually the high water table beneath hills decreases to the level of valleys particularly during dry periods.
- If the permeability of the ground remains uniform, the velocity of groundwater flow increases with an increasing gradient of slope of the water table (hydraulic gradient).



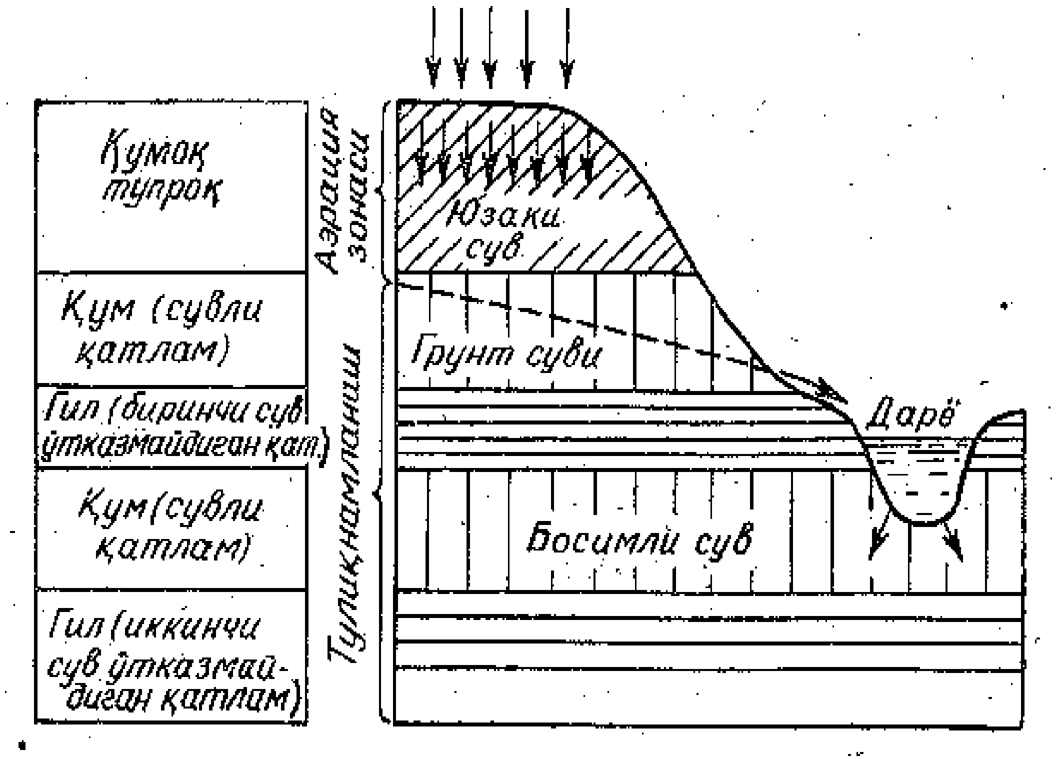
Favourable conditions for spring formation.

TYPES OF UNDERGROUND WATER ACCORDING TO THE CONDITIONS OF ITS OCCURRENCE

- ❖ The classification of groundwater according to its location in the earth's crust has an important place in hydrogeology.

- ❖ Groundwater is divided into the following types according to the location:
  - ✓ surface water,
  - ✓ ground water,
  - ✓ interlayer water.

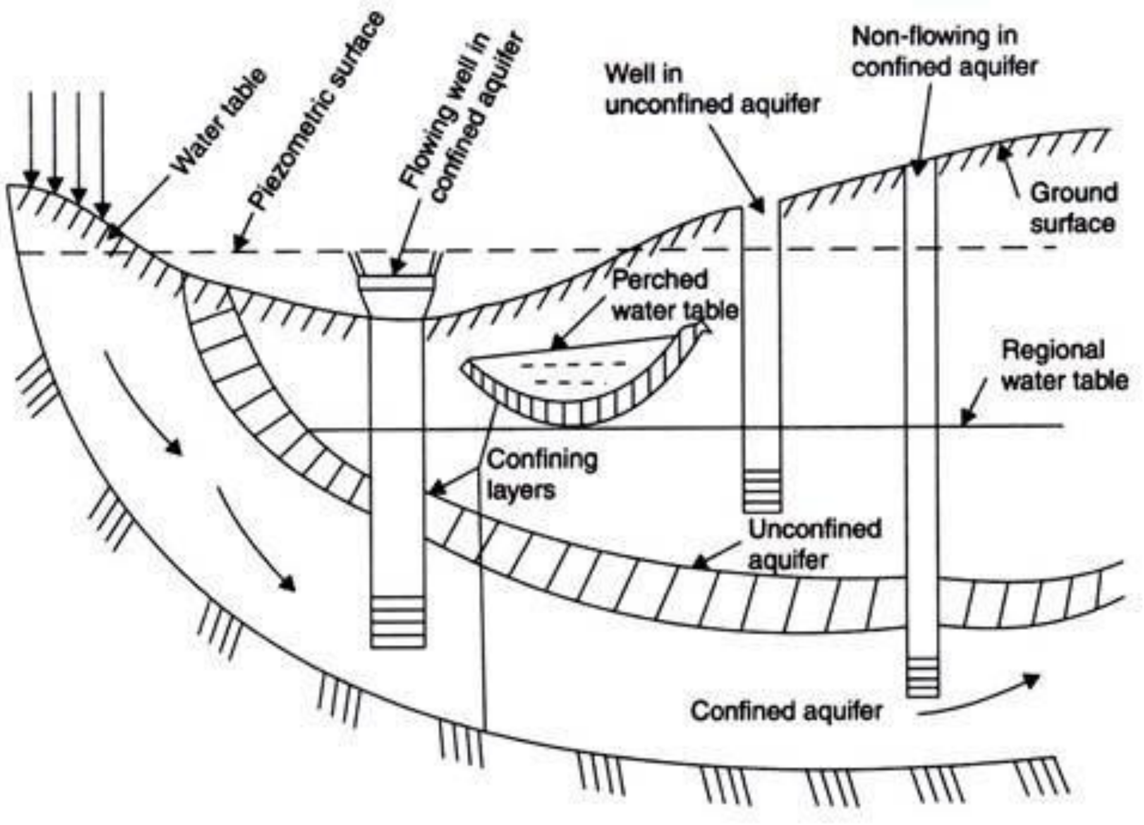
- ❖ In addition to groundwater in these main groups, there are also karst and mineral waters between specially formed cracks.



TYPES OF AQUIFERS

- A geological formation that is water bearing or saturated with water and is capable of yielding sufficient quantity of water for economic exploitation is termed as aquifers. Aquifer serves as a transmission conduct from storage reservoirs. It transports water from recharge area to surface bodies of water and other collecting devices. There are many types of aquifers:

1. ***Rich Aquifers***: The value of soil or rock as water bearers depends upon their porosity and size of the particles. However, high porosity does not mean that the aquifer is high water yielding. The best aquifer is that which has massive ground water reservoir at a reasonable depth. Sand and gravel of fairly uniform size and moderately compacted are the best aquifers followed by well grades and compacted sands and gravels, which too offer good water content.
2. ***Confined Aquifers***: If the water within the aquifer is confined i.e., held under pressure by an overlaying impervious stratum, the aquifer is known as confined aquifer.
3. ***Unconfined Aquifers***: If the aquifer is exposed to atmosphere or possesses a free surface, it is termed as unconfined aquifer.
4. ***Semi, Unconfined Aquifers***: If the permeability of the main aquifer is not too great to ignore the horizontal flow components in the covering layer such an aquifer is intermediate between the traditional semi- confined aquifers and the unconfined aquifer and may be termed as a semi-confined aquifer.



Types of aquifers

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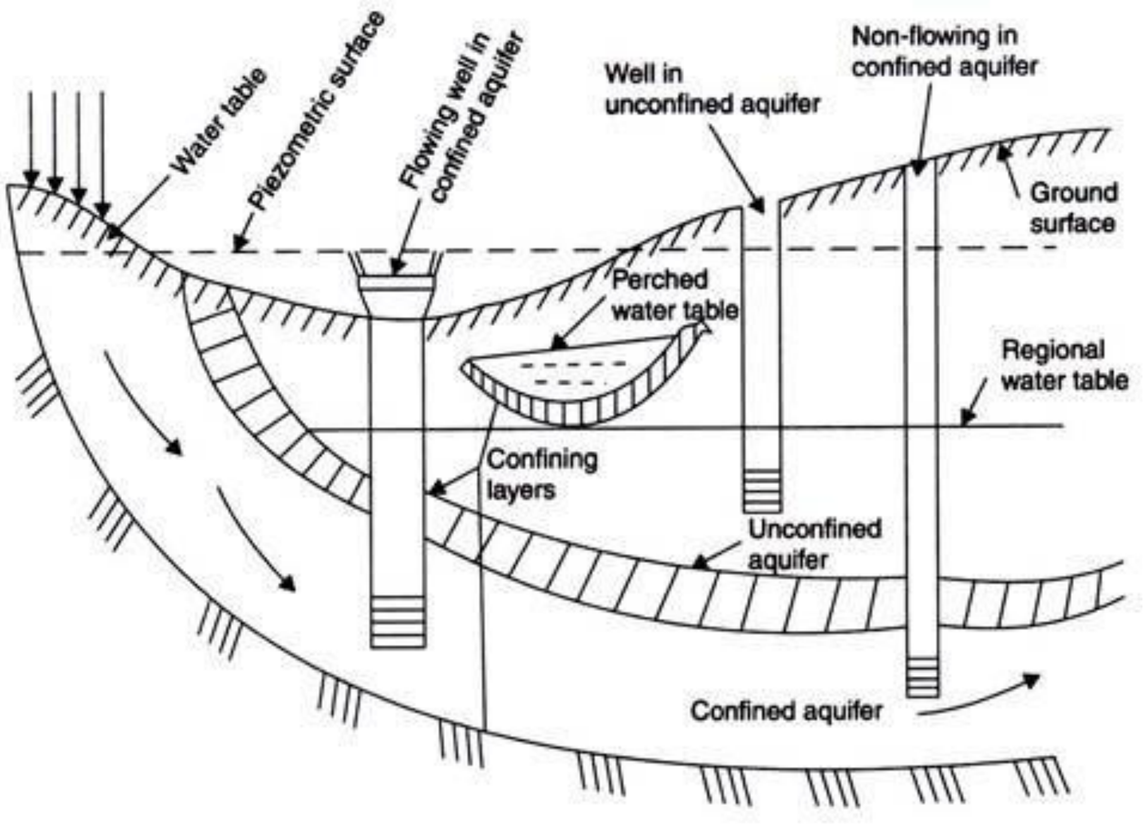
5. ***Aquifuge:*** A mask of rock matrix, which neither transmits nor stores water in significant quantity, is called an aquifuge. Such materials can confine water in an artesian aquire.
6. ***Aquiclude:*** If an aquifer is overlaid by a confined bed of impervious material, then this confined bed of overburden is known as aquiclude.
7. ***Artesian Aquifers and Artesian Wells:*** If an aquifer is overlaid by an aquiclude and if the water level in a well penetrated up to this aquifer and rises above the bottom of the overlaying aquiclude, then the aquifer is known as a confined aquifer or an artesian aquifer. The second and even lower water bearing strata will also be known as artesian aquifers.
8. ***Perched Aquifers:*** Perched aquifers are a special case, which is sometimes found to occur within an unconfined aquifer. If within the zone of saturation, an impervious deposit below a pervious deposit is found to support a body to saturated materials, and then this body of saturated materials, which is a kind of aquifers, is known as perched aquifer. The top surface of the water held in the perched aquifer is known as perched water table.



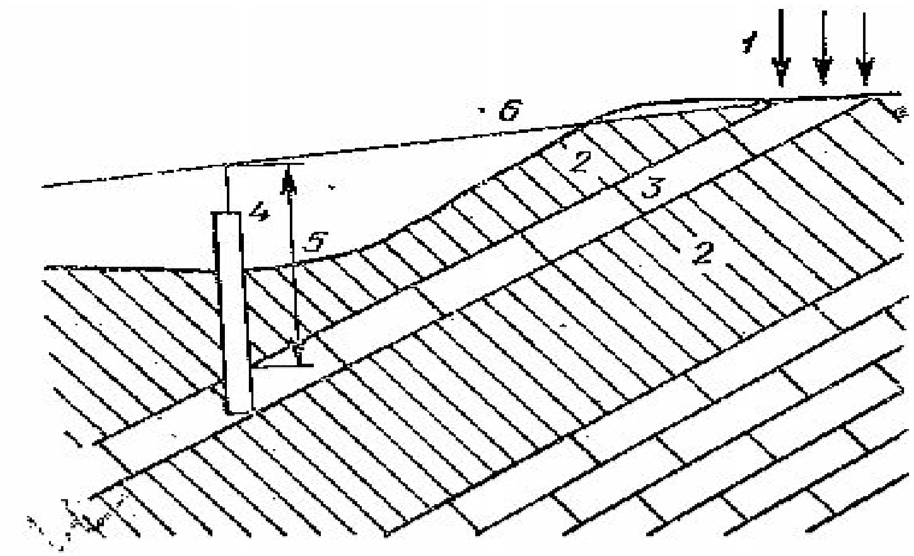
Types of aquifers

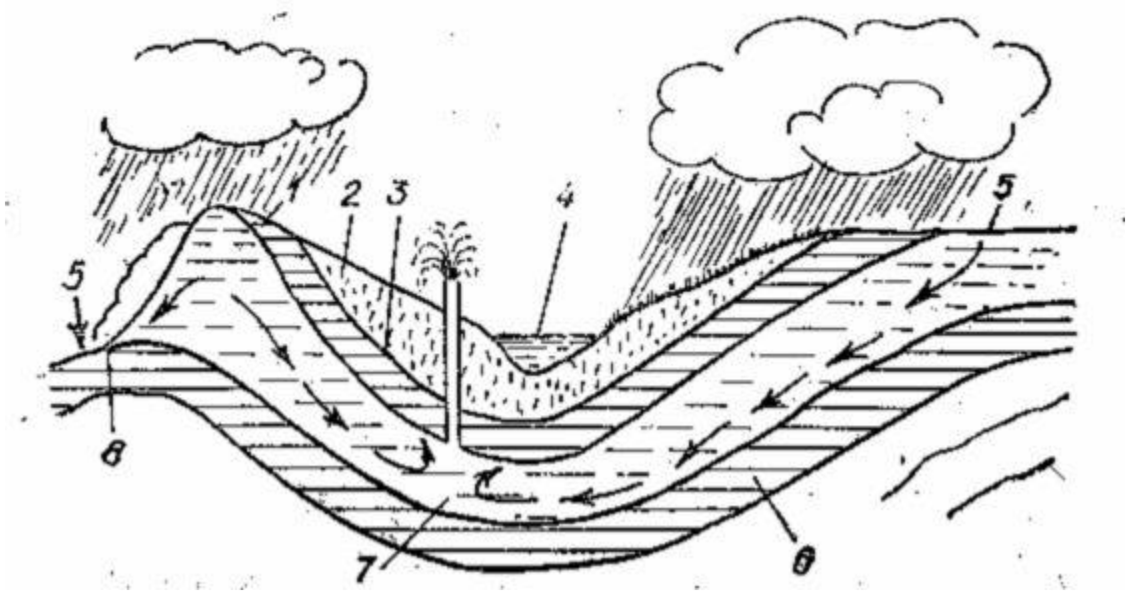
INTERLAYER GROUNDWATER

- Interlayer waters are located within two impermeable layers, the upper one being its roof and the lower layer being the base. Such waters can be pressurized or non-pressurized. Pressurized water fills the entire aquifer.
- Their saturation zone is the place where the aquifer comes to the surface. Water pressure is characterized by piezometric level. The saturation zone of pressurized waters does not coincide with the diffusion zone. Therefore, water seeps into pressure aquifers often tens or even hundreds of kilometers away from the surface.
- Pressurized water can be divided into two types: pressurized water that erupts as a fountain and pressurized water that does not erupt, pressurized water that does not erupt is called subartesian water.
- The term artesian comes from the name of the Artois region in France, which was anciently called Artesia. In 1126, high pressure water gushed out of a well dug in this region.
- Henceforth, the wells dug for the extraction of water are called artesian wells.
- The part of an artesian basin that is filled with water is called a source. When a well is dug, the part where the water level of the basin rises above the mouth of the well is called the pressure part.
- The part where artesian pressure water resources are consumed is called the discharge part. Places where artesian waters are saturated, collected, and flow out form the basin of artesian waters.
- The Syrdarya, Amudarya and Ustyurt artesian basins in our Republic and others can be an example of this. The Syr Darya artesian basin is divided into the basins of Fergana, Tashkentoldi, Shymkent, Kyzylkum, Arol and others.

INTERLAYER GROUNDWATER

- The piezometric level determines whether the water is under pressure.
  - ✓ Piezometric level has a constant and relative height.
  - ✓ Having the same absolute height
  - ✓ Line connecting piezometric levels are called hydroisopes.
  - ✓ Pressurized water saturation
  - ✓ It is more mineralized than ground water due to its long-term contact with rocks.

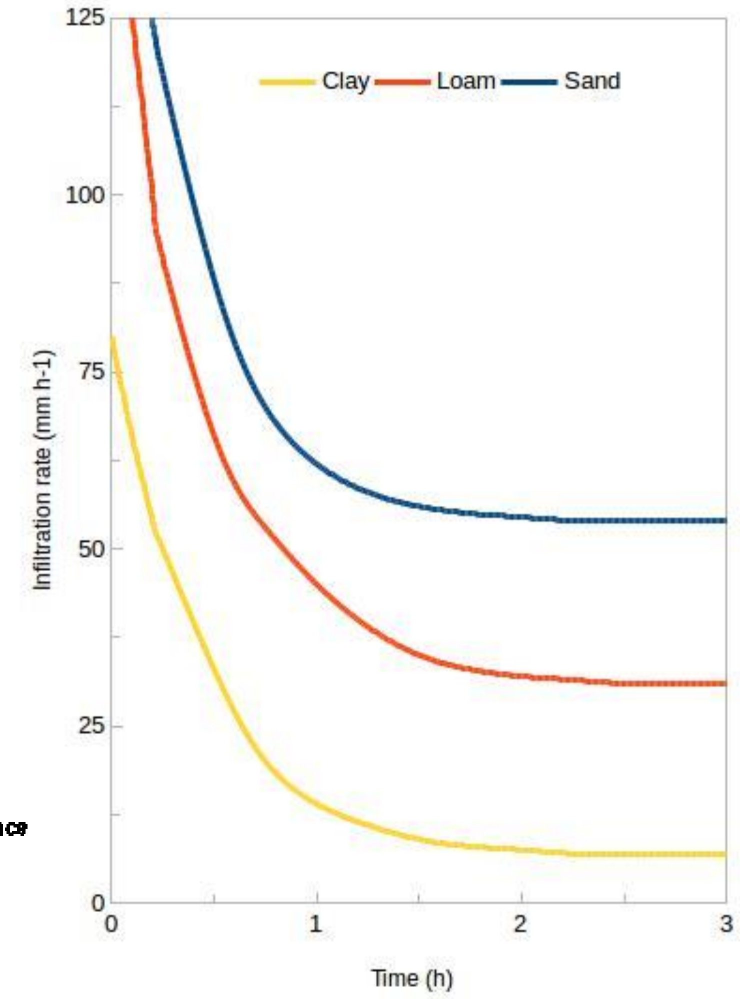




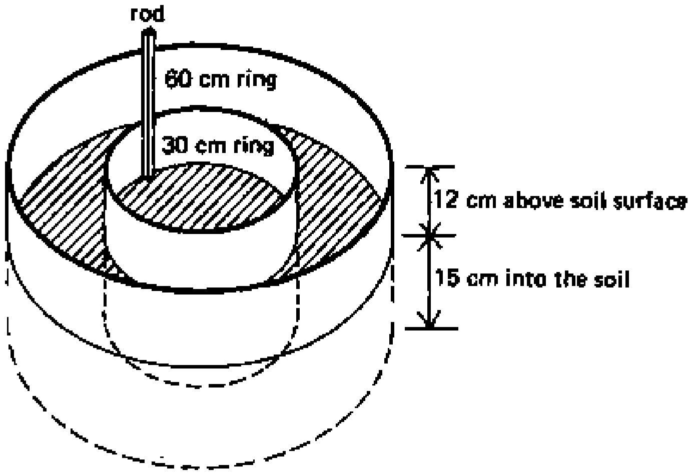
Cut of the artesian basin: 1 – waterproof layer; 2 – soil water; 3 – ground water; 4 – river; 5 - spring; 6 – underground water going down between the layers; 7 – rising underground water between layers; 8 – waterproof layer.

MOVEMENT OF UNDERGROUND WATER

- The transfer of moisture into the soil occurs as a result of the absorption-infiltration process. Water formed from atmospheric precipitation falls on dry soil and is initially absorbed by the surface of the soil under the influence of capillary forces. Little by little, very small spaces are filled. When they are full, they move downwards due to gravity. This will be laminar mode motion. As mentioned above, soils and grunts have relatively large voids and cracks. Water can pass through them to deep layers in the form of turbulent mode movement. This process is called inflation.



- For quantitative characterization of seepage/infiltration, its speed and total amount are used. Infiltration rate is defined as the amount of water flow per water depth per unit of time. Cumulative amount characterizes the absorbed water in a certain time. The rate of seepage/infiltration depends not only on the natural properties of the soil, but also on their moisture content. If the soil is dry, its rate of absorption is high. At the onset of rain, the rate of absorption is close to the rate of rainfall, that is, the rain that falls is completely absorbed into the soil. As soil moisture increases, the absorption rate decreases and remains constant after a certain period of time.



- The variation of the creep rate with time can be determined using the following expression:

$$f_t = f_0 \cdot e^{-c \cdot t}$$

where f_t is the rate of shrinkage at time *t*,

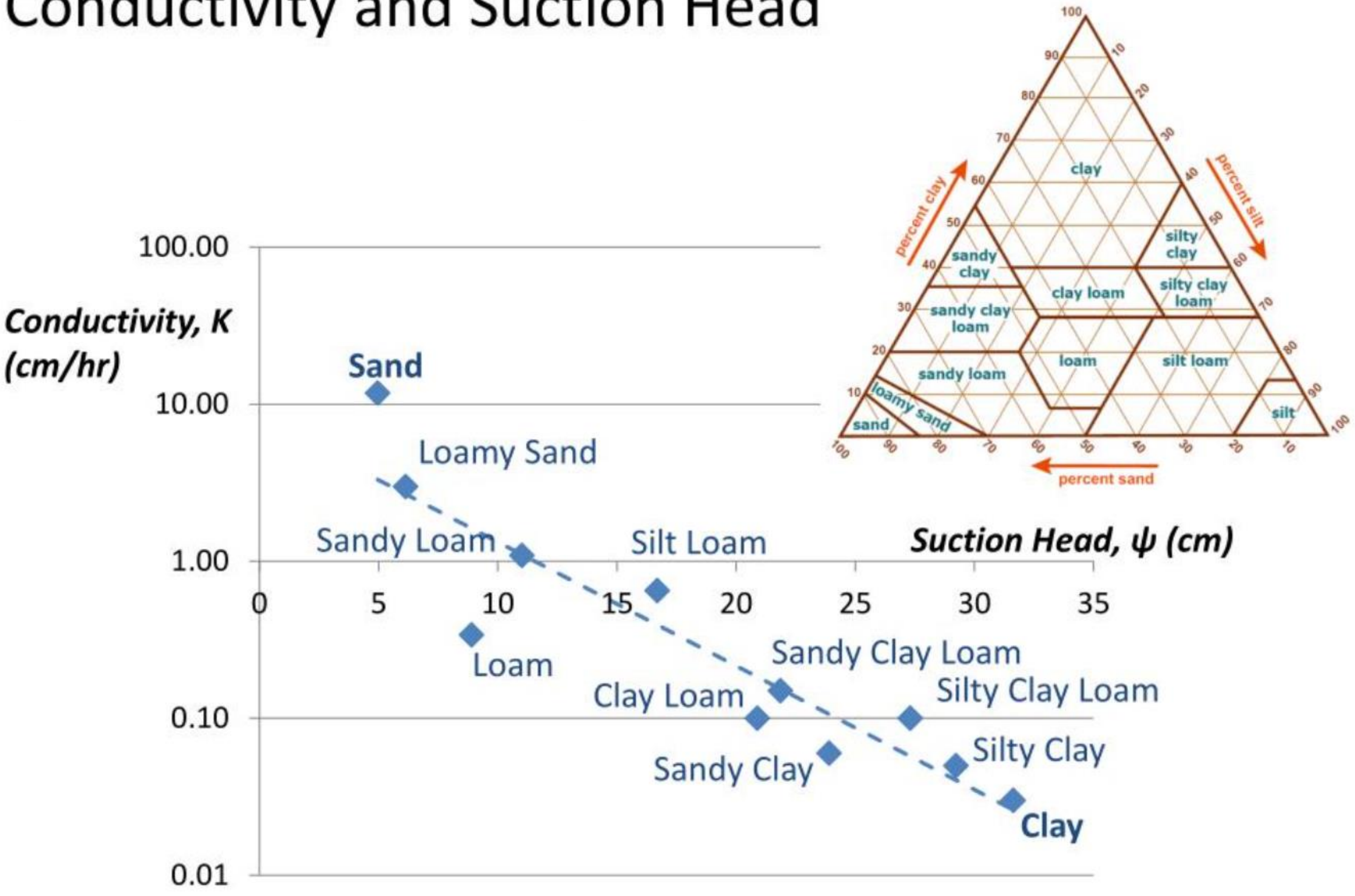
f_0 is the initial rate of shrinkage,

e is the base of the natural logarithm,

c is the quantity characterizing the physical properties of the soil.

- The above-mentioned laminar and turbulent motion occurs under the influence of hydrostatic pressure. Water moves from the upper level to the lower level. Under natural conditions, if the level of open basins (rivers, lakes) is below the water level of the water horizon, the underground water moves in this direction, otherwise, the movement of water in the direction of the soil can be observed.

Conductivity and Suction Head



QUESTIONS?

SYLLABUS

Course Meeting Times – Lectures&Practices: Two sessions / week, ~ 1.5 hours / session

Exams – In-class midterm and a final exam.

Course aim

The purpose of teaching the subject is to study the fundamentals of the theory of filtration and the calculation methods of its parameters in the design and construction of hydraulic structures from the subject "Groundwater hydraulics and filtration in structures", which is important for the formation of highly qualified personnel working in water management, construction and other fields as well as to acquire skills and abilities, and to apply theoretical and practical knowledge in concrete practice.

Course:	Groundwater hydraulics and filtration in structures
Course type:	mandatory
Course code:	YSG5104
Year:	1
Semester:	1
Education form:	daytime
Form of classes and allocated hours:	120
Lectures	30
Practical lessons	30
Independent study	60
Credit amount:	4
Evaluation form:	final control
Course language:	english

COURSE (LECTURES) OUTLINE

#	Covered topics
L1	Introduction of the course (Syllabus). Subject of groundwater hydraulics and filtration in structures.
L2	Flow types of groundwater. Basic law of laminar filtration.
L3	Filtration speed. Filtration coefficient. Methods of determining the filtration coefficient.
L4	The differential equation of the slowly changing no pressure movement of groundwater.
L5	Filtration in homogeneous and heterogeneous grounds.
L6	Methods of determining the depression curve in laminar filtration.
L7	Groundwater inflow into vertical wells.
L8	Hydraulic calculation of horizontal closed drains.
L9	Seepage from canals. Methods of calculating seepage from canals.
L10	Filtration in hydrotechnical structures. Pressured filtration in the ground of hydrotechnical structures.
L11	Approximate analytical methods of filtration calculations in hydrotechnical structures.
L12	The method of electrohydrodynamic analogies (EHDA) in calculation of filtration. Filtration in ground dams.
L13	The filtration in earthen dams in permeable foundation.
L14	Filtration in high ground dams. Unstable filtration in ground structures.
L15	Testing of filtration in the laboratory on a model of the facility and in the actual condition.