

1  **Groundwater**


Earth 9th Edition – Chapter 17

2  **Groundwater: summary in haiku form**

The grass is greener
over the septic system
said Erma Bombeck.


3  **Key Concepts**

- Groundwater and the "water table."
- The water table.
- Storage and movement of groundwater.
- Springs.
- Wells.
- Problems associated with groundwater.
- Underground erosion: Caverns and karst terrains.

4  **Importance of groundwater**

- Groundwater is water found in the pores of soil and sediment, plus narrow fractures in bedrock
- Groundwater is the largest reservoir of fresh water that is readily available to humans

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6  **Importance of groundwater**

- Geological role of groundwater
 - ☒ As an erosional agent, dissolving groundwater produces
 - ◆ Sinkholes
 - ◆ Caverns
 - ☒ Groundwater serves as an equalizer of streamflow

7  **Distribution of groundwater**

- Belt of soil moisture – water held by molecular attraction on soil particles in the near-surface zone
- Zone of saturation
 - ☒ Formation
 - ◆ Water not held as soil moisture percolates downward

8  **Distribution of groundwater**

- Zone of saturation
 - ☒ Formation
 - ◆ Water reaches a zone where all of the open spaces in sediment and rock are completely filled with water
 - ◆ Water within the pores is called groundwater
 - ☒ Water table – the upper limit of the zone of saturation

9  **Distribution of groundwater**












- Capillary fringe
 - ☒ Extends upward from the water table
 - ☒ Groundwater is held by surface tension in tiny passages between grains of soil or sediment

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10  **Distribution of groundwater**

- Zone of aeration
 - ☒ Area above the water table
 - ☒ Includes the capillary fringe and the belt of soil moisture
 - ☒ Water cannot be pumped by wells

11  **Distribution of groundwater**

- 12  **The water table**
- The water table is the upper limit of the zone of saturation
 - Variations in the water table
 - ☒ Depth is highly variable
 - Varies seasonally and from year to year
 - ☒ Shape is usually a subdued replica of the surface topography
- 13  **The water table**
- Variations in the water table
 - ☒ Factors that contribute to the irregular surface of the water table
 - Water tends to “pile up” beneath high areas
 - Variations in rainfall
 - Variations in permeability from place to place
- 14  **The water table**
- Interaction between groundwater and streams
 - ☒ Constitutes a basic link in the hydrologic cycle
 - ☒ Three types of interactions
 - Gaining streams – gain water from the inflow of groundwater through the streambed
 - Losing streams – lose water to the groundwater system by outflow through the streambed
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- 16  **The water table**
- Interaction between groundwater and streams
 - ☒ Interactions
 - A combination of the first two – a stream gains in some sections and loses in other areas
- 17  **Storage and movement of groundwater**
- Porosity – percentage of total volume of rock or sediment that consists of pore spaces
 - ☒ Determines how much groundwater can be stored
 - ☒ Variations can be considerable over short distances
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- 19  **Storage and movement of groundwater**
- Permeability, aquitards, and aquifers
 - ☒ Permeability – the ability of a material to transmit a fluid
 - ☒ Aquitard – an impermeable layer that hinders or prevents water movement (such as clay)
 - ☒ Aquifer – permeable rock strata or sediment that transmits groundwater freely (such as sands and gravels)
- 20  **Storage and movement of groundwater**
- Movement of groundwater
 - ☒ Exceedingly slow – typical rate of movement is a few centimeters per day
 - ☒ Energy for the movement is provided by the force of gravity
 - ☒ Darcy’s Law – if permeability remains uniform, the velocity of groundwater will increase as the slope of the water table increases
- 21  **Storage and movement of groundwater**
- Movement of groundwater
 - ☒ Darcy’s Law
 - Hydraulic gradient – the water table slope, determined by dividing the vertical difference between the recharge and discharge points by the length of flow between these points
 - Hydraulic head – the vertical difference between the recharge and discharge points
- 22  **Storage and movement of groundwater**
- The movement of groundwater is measured directly using

- ☒ Various dyes
- ☒ Carbon-14
- 23 **Hydraulic gradient**
- 24 **Springs**
 - Springs
 - ☒ Occur where the water table intersects Earth's surface
 - ☒ Natural outflow of groundwater
 - ☒ Can be caused by an aquitard creating a localized zone of saturation which is called a perched water table
- 25 **Spring resulting from a perched water table**
- 26 **Hot springs and geysers**
 - Hot springs
 - ☒ Water is 6 - 9°C warmer than the mean annual air temperature of the locality
 - ☒ The water for most hot springs is heated by cooling of igneous rock
- 27 **Distribution of hot springs and geysers in the U.S.**
- 28 **Hot springs and geysers**
 - Geysers
 - ☒ Intermittent hot springs
 - ☒ Water erupts with great force
 - ☒ Occur where extensive underground chambers exist within hot igneous rock
 - ☒ Groundwater heats, expands, changes to steam, and erupts
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- 33 **Hot springs and geysers**
 - Geysers
 - ☒ Chemical sedimentary rock accumulates at the surface
 - ◆ Siliceous sinter (from dissolved silica)
 - ◆ Travertine (from dissolved calcium carbonate)
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- 35 **Wells**
 - To ensure a continuous supply of water, a well must penetrate below the water table
 - Pumping of wells can cause
 - ☒ Drawdown (lowering) of the water table
 - ☒ Cone of depression in the water table
- 36 **Cone of depression in the water table**
- 37 **Wells**
 - Artesian well – a situation in which groundwater under pressure rises above the level of the aquifer
 - ☒ Types of artesian wells
 - ◆ Nonflowing – pressure surface is below ground level
 - ◆ Flowing – pressure surface is above the ground
 - ☒ Not all artesian systems are wells, artesian spring also exist
- 38 **Artesian well resulting from an inclined aquifer**
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- 43 **Problems associated with groundwater withdrawal**
 - Treating groundwater as a nonrenewable resource
 - ☒ In many places the water available to recharge the aquifer falls significantly short of the

amount being withdrawn


- Subsidence

- ☒ Ground sinks when water is pumped from wells faster than natural recharge processes can replace it (San Joaquin Valley of California)

44  **Problems associated with groundwater withdrawal**

- Saltwater contamination

- ☒ Excessive groundwater withdrawal causes saltwater to be drawn into wells, thus contaminating the freshwater supply
- ☒ Primarily a problem in coastal areas

45  **Saltwater contamination**

46  **Groundwater contamination**

- One common source is sewage

- ☒ Extremely permeable aquifers, such as coarse gravel, have such large openings that groundwater may travel long distances without being cleaned
- ☒ Sewage often becomes purified as it passes through a few dozen meters of an aquifer composed of sand or permeable sandstone

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49  **Groundwater contamination**

- Sinking a well can lead to groundwater pollution problems

- Other sources and types of contamination include substances such as:

- ☒ Highway salt
- ☒ Fertilizers
- ☒ Pesticides
- ☒ Chemical and industrial materials

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52  **Geologic work of groundwater**


- Groundwater dissolves rock

- ☒ Groundwater is often mildly acidic
 - Contains weak carbonic acid
 - Forms when rainwater dissolves carbon dioxide from the air and from decaying plants
- ☒ Carbonic acid reacts with calcite in limestone to form calcium bicarbonate, a soluble material

53  **Geologic work of groundwater**

- Caverns

- ☒ Most caverns are created by acidic groundwater dissolving soluble rock at or just below the surface in the zone of saturation
- ☒ Features found within caverns
 - They form in the zone of aeration

54  **Geologic work of groundwater**

- Caverns

- ☒ Features found within caverns
 - Composed of dripstone (travertine)
 - Calcite deposited as dripping water evaporates
 - Collectively, they are called speleothems
 - Includes stalactites (hanging from the ceiling) and stalagmites (form on the floor of a cavern)

55  **Speleothems in Carlsbad Caverns National Park**

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- 58 ***"Soda straws" in Carlsbad Caverns National Park***
- 59 ***Halite "Soda straws"***

(Grand Canyon National Park)

- 60 ***Lewis & Clark Caverns State Park, Montana***

- 61 **Geologic work of groundwater**

- **Karst topography**

- ☒ Landscapes that have been shaped mainly by the dissolving power of groundwater

- ☒ Some common features include

- Irregular terrain

- Sinkhole or sinks (formed by groundwater slowly dissolving the bedrock often accompanied by collapse)

- Striking lack of surface drainage (streams)

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- 66 **End of Chapter**