SAMPLE

Earth's Dynamic Systems: Groundwater

The Hidden Water Below

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Contents

Introduction

Chapter 1: The Discovery of Groundwater

Chapter 2: Understanding Groundwater

Chapter 3: Key Characteristics of Groundwater

Chapter 4: The Science Behind Groundwater

Chapter 5: Observation and Measurement of Groundwater

Chapter 6: Important Features of Groundwater

Chapter 7: Groundwater in Context

Chapter 8: Modern Understanding of Groundwater

Chapter 9: Research and Exploration of Groundwater

Chapter 10: Significant Discoveries About Groundwater

Chapter 11: Challenges and Mysteries of Groundwater

Chapter 12: Future Directions in Groundwater Research

Chapter 13: Fun Facts and Trivia About Groundwater

Chapter 14: Conclusion: The Significance of Groundwater

Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

Groundwater is the water present beneath Earth's surface in rock and soil pore spaces and in the fractures of rock formations. About 30 percent of all readily available fresh water in the world is groundwater. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table.

Groundwater is recharged from the surface; it may discharge from the surface naturally at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells. Hydrogeology, sometimes called groundwater hydrology, is the science of how this hidden water is distributed and how it moves.

Typically, groundwater is thought of as water flowing through shallow aquifers, but, in the technical sense, it can also contain soil moisture, permafrost (frozen soil), immobile water in very low permeability bedrock, and deep geothermal or oil formation water. Groundwater is hypothesized to provide lubrication that can possibly influence the movement of faults. It is likely that much of Earth's subsurface contains some water, which may be mixed with other fluids in some instances.

Groundwater is often cheaper, more convenient and less vulnerable to pollution than surface water. Therefore, it is commonly used for public drinking water supplies. For example, groundwater provides the largest source of usable water storage in the United States, and California annually withdraws the largest amount of groundwater of all the states. Underground reservoirs contain far more water than the capacity of all surface reservoirs and lakes in the US, including the Great Lakes. Many municipal water supplies are derived solely from groundwater.

Chapter 1: The Discovery of Groundwater

Major sources include industrial and household chemicals and garbage landfills, excessive fertilizers and pesticides used in agriculture, industrial waste lagoons, tailings and process wastewater from mines, industrial fracking, oil field brine pits, leaking underground oil storage tanks and pipelines, sewage sludge and septic systems. Additionally, groundwater is susceptible to saltwater intrusion in coastal areas and can cause land subsidence when extracted unsustainably, leading to sinking cities (like Bangkok) and loss in elevation (such as the multiple meters lost in the Central Valley of California).

These issues are made more complicated by sea level rise and other effects of climate change, particularly those on the water cycle. Earth's axial tilt has shifted 31 inches (79 cm) because of human groundwater pumping. Groundwater is fresh water located in the subsurface pore space of soil and rocks. It is also water that is flowing within aquifers below the water table.

Sometimes it is useful to make a distinction between groundwater that is closely associated with surface water, and deep groundwater in an aquifer (called "fossil water" if it infiltrated into the ground millennia ago). Groundwater can be thought of in the same terms as surface water: inputs, outputs and storage. The natural input to groundwater is infiltration from surface water, which must then percolate downward to reach the groundwater.

The natural outputs from groundwater are springs and seepage to the oceans.

Groundwater storage can be much larger (in volume) compared to its inputs than surface water and have a slower turnover rate, though this depends on the features of the aquifer. This difference makes it easy for humans to use groundwater unsustainably for a long time without severe consequences. Nevertheless, over the long term the average rate of infiltration above a groundwater source plus input from streams is the upper bound for average consumption of water from that source.

Groundwater is naturally replenished by surface water from precipitation, streams, and rivers when this recharge reaches the water table. Groundwater can be a long-term 'reservoir' of the natural water cycle (with residence times from days to millennia), as opposed to short-term water reservoirs like the atmosphere and fresh surface water (which have residence times from minutes to years). Deep groundwater (which is quite distant from the surface recharge) can take a very long time to complete its natural cycle.

The Great Artesian Basin in central and eastern Australia is one of the largest

confined aquifer systems in the world, extending for almost 2 million km2. By analysing the trace elements in water sourced from deep underground, hydrogeologists have been able to determine that water extracted from these aquifers can be more than 1 million years old. By comparing the age of groundwater obtained from different parts of the Great Artesian

Basin, hydrogeologists have found it increases in age across the basin.

Where water recharges the aquifers along the Eastern Divide, ages are young. As groundwater flows westward across the continent, it increases in age, with the oldest groundwater occurring in the western parts. This means that in order to have travelled almost 1000 km from the source of recharge in 1 million years, the groundwater flowing through the Great Artesian Basin travels at an average rate of about 1 metre per year.

The high specific heat capacity of water and the insulating effect of soil and rock can mitigate the effects of climate and maintain groundwater at a relatively steady temperature. In some places where groundwater temperatures are maintained by this effect at about 10 °C (50 °F), groundwater can be used for controlling the temperature inside structures at the surface. For example, during hot weather relatively cool groundwater can be pumped through radiators in a home and then returned to the ground in another well.

During cold seasons, because it is relatively warm, the water can be used in the same way as a source of heat for heat pumps that is much more efficient than using air. Groundwater makes up about thirty percent of the world's fresh water supply, which is about 0.76% of the entire world's water, including oceans and permanent ice. About 99% of the world's liquid fresh water is groundwater.

Global groundwater storage is roughly equal to the total amount of freshwater stored in the snow and ice pack, including the north and south poles. This makes it an important resource that can act as a natural storage that can buffer against shortages of surface water, as in during times of drought.

The volume of groundwater in an aquifer can be estimated by measuring water levels in local wells and by examining geologic records from well-drilling to determine the extent, depth and thickness of water-bearing sediments and rocks. Before an investment is made in production wells, test wells may be drilled to measure the depths at which water is encountered and collect samples of soils, rock and water for laboratory analyses. Pumping tests can be performed in test wells to determine flow characteristics of the aquifer.

The characteristics of aquifers vary with the geology and structure of the

substrate and topography in which they occur. In general, the more productive aquifers occur in sedimentary geologic formations. By comparison, weathered and fractured crystalline rocks yield smaller quantities of groundwater in many environments. Unconsolidated to poorly cemented alluvial materials that have accumulated as valley-filling sediments in major river valleys and geologically subsiding structural basins are included among the most productive sources of groundwater.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.