Title:	Water, Water Everywhere
Source:	The Water Sourcebook Series, U.S. Environmental Protection Agency
Subject(s):	Science, Reading
Grade(s):	9-12
Objectives:	Students will understand the amount of water on Earth, identify methods of water conservation, evaluate current and future demands on water resources, discuss the hydrologic cycle, and investigate local agencies involved with monitoring water quality and regulating water use.
Summary:	The activity begins with students reading an article about the world's water resources. The article discusses the availability of fresh water on Earth, the hydrologic cycle, sources of fresh water for human consumption, and water scarcity. Discussion questions about the article, topics for further student research, and suggested follow-up and extension activities are provided.
Modifications:	Instead of a field trip to a water treatment plant, take a virtual tour of the Blue Plains Advanced Wastewater Treatment Plant online at http://www.dcwasa.com/about/model_flash.cfm.
Standards:	SCSh9. Students will enhance reading in all curriculum areas.
	SEC4. Students will analyze biogeochemical cycles and the flow of energy in ecosystems.
	SEC5. Students will assess the impact of human activities on the natural world, and research how ecological theory can address current issues facing our society, locally and globally.
	SEV1. Students will investigate the flow of energy and cycling of matter within an ecosystem and relate these phenomena to human society.
	SEV4. Students will understand and describe availability, allocation and conservation of energy and other resources.
	SEV5. Students will recognize that human beings are part of the global ecosystem and will evaluate the effects of human activities and technology on ecosystems.

WATER, WATER EVERYWHERE

9-12

OBJECTIVES

The student will do the following:

1. Determine how much water there is on the Earth.

2. Identify ways of conserving water.

3. Evaluate the future demand for water.

4. Reproduce the hydrologic cycle.

5. Determine what state or territorial agencies investigate, monitor, or regulate water resources in the state or territory.

SUBJECT:
Science (Physical)

TIME:
3 class periods
optional 1 field trip

MATERIALS:
The World's Water article
optional field trip and /or water analysis kit

BACKGROUND INFORMATION

With many rivers, lakes, and streams in the United States, you would think that there would never be a water shortage. Because we share our borders with Canada and Mexico, we also share water resources. Water from lakes and rivers, as well as groundwater, is shared. This creates a need for cooperation and planning between the United States and our bordering countries. With the increasing demand for fresh water, we can no longer take our water supply for granted. We now realize that our present water resources are limited. Today's students will be challenged to find technical and social solutions to meet future U.S. water demands.

<u>Terms</u>

atmospheric water: water found in vapor form in the atmosphere

condensation: (1) the process of changing from a vapor to a liquid; (2) a liquid obtained by the coming together of a gas or vapor

evaporation: the process of changing from a liquid to a vapor

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation

hydrologic cycle: the cyclical process of water's movement from the atmosphere, its inflow an temporary storage on and in land, and its outflow to the oceans; cycle of water from the atmosphere, by condensation and precipitation, then its return to the atmosphere by evaporation and transpiration

salinity: the amount of salt dissolved in water

transpiration: process in which water absorbed by the root systems of plants, moves up through the plants, passes through pores (stomata) in their leaves or other parts, and then evaporates into the atmosphere as water vapor; the passage of water vapor from a living body through membrane or pores

vadose zone: the zone of aeration between the Earth's surface and the water table; area of th soil that contains both air and water; same as unsaturated zone--zones between land surface and the water table

water analysis: series of tests to determine various chemical or physical characteristics of a sample of water

zone of saturation: that region below the surface in which all voids are filled with liquid

ADVANCE PREPARATION

A. Make copies and have students read "*The World's Water.*"

B. The article is provided to explain the world water supply and nature's methods of replenishing fresh water. This inventory of the world's water and description of the water cycle provides the initial information for discussion.

C. Class exercises may then expand on this information to learn what technology can do to provide sufficient water for the future.

PROCEDURE

I. Activity

A. Fill out Student Sheet on Hydrologic Cycle. (See activity on Hydrologic Cycle.)

B. Determine the source of water for your school and visit a local treatment plant.

C. From the total annual rainfall given in the article, calculate the average annual rainfall over the Earth.

D. Can glaciers and icecaps be used for fresh water? Are they limited, or are they being replenished?

E. Study past droughts in this century.

F. Evaluate the future demand for water in your city based on the patterns of population and industrial growth.

G. List short term and long term methods of conserving water.

H. If people in your city decided on a very austere use of water, how would it affect the community?

I. Discuss possible conflicts that could arise from the increased demand for water between countries and states.

II. Follow-up

A. Have students develop a water trivia sheet from “The World’s Water” article. Use these to develop quiz questions.

B. Name one state or territorial agency which regulates, monitors, or investigates water resources in your state or territory. (Contact state/territorial environmental management agency or geological survey.)

C. Write to research companies, such as Phillips Petroleum, who advertise that they can purify sea water for drinking water. Learn the way this is done and the potential for doing it in your area.

D. Investigate water’s role in providing the world’s energy (HINT: Hydropower - hydroelectric and tidal power).

III. Extensions

A. In 1986, the Great Salt Lake in Utah was at its highest level in recorded history. The Great Lakes were also considered high and were eroding their shores. Can you determine why this occurred?

B. Discuss this question: Do city officials encourage expanded use of water because it brings in revenue?

C. Build a small, low-cost solar still. (This may require a little research.)

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Forrester, F. H., An Inventory for the World's Water, (ESO2), Weatherwise, Helen Dwight Reid Education Foundation, Heldref Publications, 1319 18th St. N.W., Washington, D.C. 20036-1802, April 1985.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

THE WORLD'S WATER

By Frank H. Forrester

Nobody really knows exactly how much water exists around the world. The sheer volume of our planet's water -- locked in glaciers, stored in lakes, detained in underground rocks, or moving in the atmosphere, river and seas -- almost defies the imagination. Even the hottest and driest parcels of air overlying the world's most arid regions contain at least traces of water vapor as part of the Earth's aerial canopy of gases. In the same arid regions, dry though the surfaces may be, abundant water often can be found in deep subsurface rock formations.

The waters of the world have been inventoried, roughly of course, but within generally accepted limits of hydrologic research. Like oil or gas inventories, estimates of water might be broken down into two major categories: known or identified reserves and unknown or inferred resources. Water contained in large glaciers, many rivers, lakes, and seas can be identified or estimated with reasonably high percentages of accuracy. Estimates of groundwater resources, however, often based on indirect evidence and measurements, are compiled with varying degrees of uncertainty. Even today, the United States is far from completing the task of probing suspected sources of groundwater and determining the amounts the hydrated rocks might yield.

Some research hydrologists of the U.S. Geological Survey have estimated that the world's water supply--liquid, frozen, and vapor- - totals 326 million cubic miles (a cubic mile is equal to about 1. 1 trillion gallons of water). If this total supply were in liquid form and poured upon the 50 United States, the land surface would be submerged to a depth of about 90 miles.

With "water, water everywhere," why are there shortages? To answer this question and others related to a variety of water problems, it is instructive --perhaps imperative -- to consider water on a planetary scale.

Most people are aware that water is unevenly distributed on the Earth's surface in oceans, rivers, and lakes, but few realize the disproportion of the distribution. Further, few realize the manner in which "hidden" water is distributed - underground, in glacial ice, and in the atmosphere. Finally, one of the most important concepts of hydrology, known as the hydrologic cycle, is often poorly perceived by the public. This endless cycle, a global natural distillation and pumping system, has been going on since the first clouds formed and the first rains fell, transferring water time and again from the surface of the land and water to the sky and back again, keeping our planet fed with the liquid of life. The waters of long geologic history are the waters of today; little has been added or lost.

An Inventory of the World's Water

Views of the Earth from space confirm one of the first lessons of geography in elementary schools--water covers about 70 percent of the Earth's surface. But this one-dimensional view, suggestive as it is, provides only a beginning hint in preparing a world water inventory. There are a host of surprises to be found in such an inventory; one is the realization that man gets by on an incredibly small amount of the total supply of 326 million cubic miles. Usable fresh water amounts to less that 1 percent of the total!

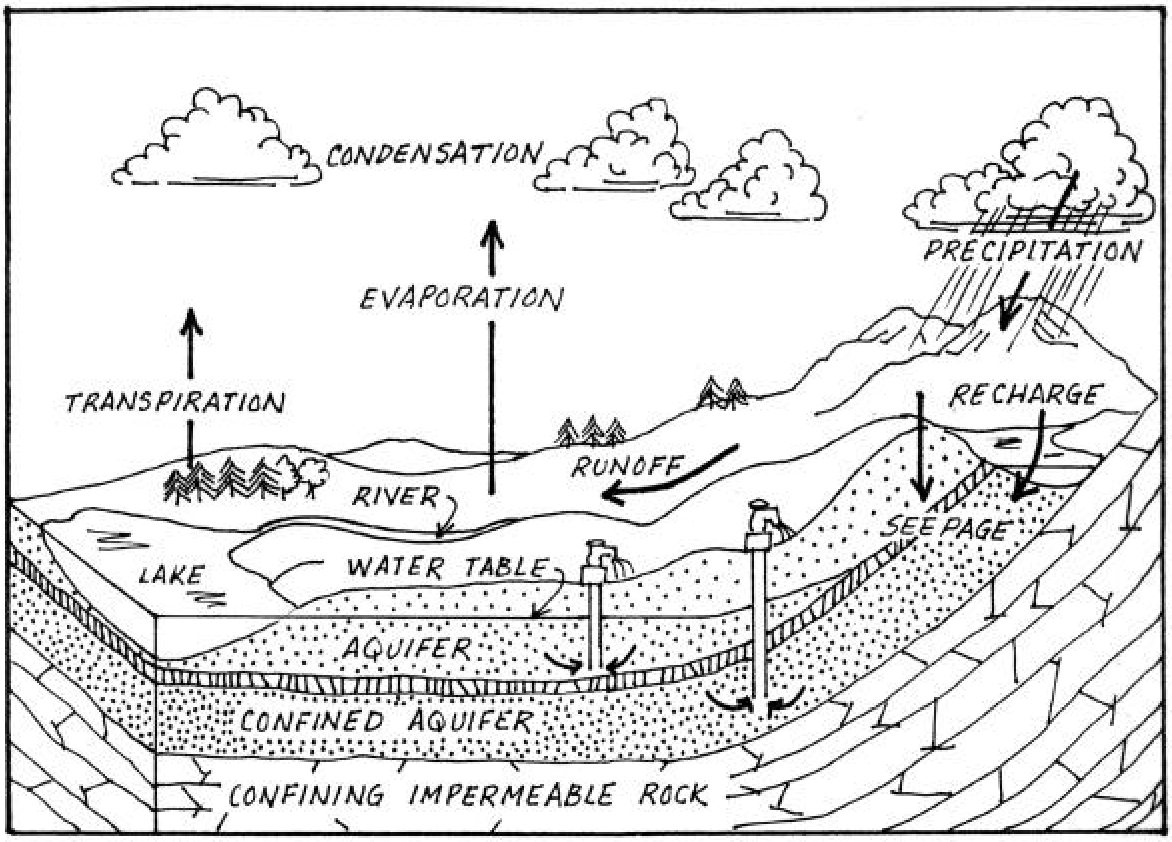
It should come as no surprise to find that the world's oceans -- covering 139.5 million square miles of the Earth's surface, with their basins averaging about 12,500 feet in depth -- comprise the bulk of the world's water. It may be an eye-opener, however, to learn that the approximately 320 million cubic miles of sea water constitute about 97.2 percent of the planet’s total water supply. Every other source of water pales in statistical comparison to the oceans, but the importance to mankind of other, lesser sources is not revealed by sheer statistics.

The next items on the world water balance sheet are the planet’s icecaps and glaciers. The amount of water stored in frozen form, though a far second to the oceans, nonetheless totals an impressive 7 million cubic miles, representing 2.15 percent of the world's water. Of the frozen water, mountain glaciers, such as those of the Alps in Europe, the Himalayas of Asia, the Cascades of North America, and small icecaps in the world, have a total volume of only about 50,000 cubic miles - an insignificant fraction of the world's water. But the Greenland and Antarctic icecaps are entirely different matters.

About 667,000 square miles in area, and averaging more than 5,000 feet in thickness, the Greenland icecap represents about 630,000 cubic miles of water. If melted, the Greenland icecap would yield enough water to maintain the flow of the Mississippi River for more than 4,700 years. Even so, this is less than 10 percent of the total volume of icecaps and glaciers.

The greatest single item in the water budget of the world, aside from the oceans, is the Antarctic ice sheet. The huge southern hemisphere icecap, 1000 feet thick in some places, and covering an area of about 6 million square miles, has a total volume of between 6 and 7 million cubic miles or about 85 percent of all existing ice and about 64 percent of all water outside the oceans. If the Antarctic icecap were to melt at a suitable uniform rate, it could feed the Mississippi River for more than 50,000 years; all rivers in the United States for about 17,000 years; the Amazon River for about 5,000 years; or all the rivers of the world for about 750 years.

THE HYDROLOGIC CYCLE



THE HYDROLOGIC CYCLE of the world's water budget. Water that has evaporated from the Earth's surface may fall as precipitation many thousands of miles from where it entered the atmosphere. (Adapted from Spiegel and Graber, From Weather Vanes to Satellites.)

Thus far, we have inventoried slightly over 99 percent of the world's water: that contained in the oceans, icecaps, and glaciers. Statistically, the next ranking source of water consists of subsurface water or groundwater. Estimates of such water are broken down into three categories: vadose water (which includes surface moisture); groundwater to a depth of a half mile; and deep-lying groundwater.

Vadose Water

The average amount of soil moisture at any given time is on the order of 6,000 cubic miles for the world as a whole, an extremely small percentage of the Earth's total water but profoundly important because of the key role played by plants in the food chain. On a global scale, relatively little vegetation receives artificial irrigation; most of it depends upon soil moisture. The world volume of vadose water -- water just below the belt of soil moisture -- probably is somewhat more than that of soil moisture, say 10,000 cubic miles. Again, this is not a significant amount on a world scale; and even though not extractable by man, it is important because it is potential groundwater recharge and groundwater is extractable.

Groundwater

Below the vadose water, our planet contains a water reservoir, groundwater, known to man for thousands of years. Scripture on the Noacniari Deluge states, "The fountains of the great deep (were) broken up ." Exodus, among its many references to water and to wells, refers to "water under the Earth." Many other chronicles show that man has known from ancient times that there is much water underground. Only recently, however, have we begun to appreciate how much groundwater exists and how important it is in meeting current and future water needs.

Beneath most land areas of the world, even under deserts, mountain peaks, and some sub-sea floors, there is a zone where the pores of rocks and sediment are saturated with water. The upper limit of the saturated zone is called the water table. It may be right at the land surface as in a marsh, or it may lie hundreds of thousands of feet below the land surface as in some arid regions.

Sometimes there are surprises in groundwater discoveries. In 1965 during a geologic probe of the Atlantic sea floor about 30 miles off northern Florida by an international team of scientists aboard a research vessel, drilling struck some sub-sea rocks that contained fresh water. Pumped to the ship's deck, the water was found to be potable -- a spinoff dividend from the expedition.

In 1975, U.S. Earth scientists tapped other water-bearing rock formations under the ocean about 30 to 60 miles off the Mid-Atlantic coast. When tested, the water was found to be of surprisingly low salinity, some of it directly potable and some requiring slight treatment to reach drinking water standards. These and other potential sub-ocean deposits of fresh water are not likely to be used in the reasonably near future. They do, however, reflect the watery nature of our planet, and they are of great research value. The findings off the Atlantic coast, for example, may yield insight into such problems as salt water invasion of aquifers (subsurface, water-bearing rock formations) that are tapped by many Atlantic coast communities.

Below the water table to a depth of about a half mile in land areas of the Earth's crust, there is an estimated 1 million cubic miles of groundwater. This is probably 3,000 times greater than the volume of water in all rivers at any one time. An equal, if not greater, amount of groundwater is present at a greater depth down to some 10,000 to 15,000 feet. This deeper water, however, circulates sluggishly because its rocks are only slightly permeable. Much of the deep-lying water is not economically recoverable for human use at the present time, and a good deal of it is strongly mineralized.

Tallying all the subsurface waters of the planet, the total is a little over 2 million cubic miles or about two-thirds of one percent of the world's water. The balance is to be found in surface water (freshwater lakes, saline lakes, inland seas, and rivers) and in the atmosphere.

The Earth's land areas are dotted with hundreds of thousands of lakes. Wisconsin, Minnesota, and Finland each contain some tens of thousands. But these lakes, important though they may be locally, hold only a minor amount of the world supply of fresh water, most of which is contained in a relatively few large lakes on three continents - Africa, Asia, and North America.

Whether water is fresh or salty makes a considerable difference in its usefulness to man, and the Earth's greatest lakes fall in both categories, fresh and salt.

Lakes, Both Fresh and Salt

The volume of all the large freshwater lakes in the world aggregates nearly 30,000 cubic miles (their combined surface area is about 330,000 square miles). "Large" is a relative term for our inventory purposes. A lake is called large if its contents are 5 cubic miles or more. Thus, the listing includes the Dubawnt Lake, Canada (about 6 cubic miles), but excludes the Zurich Sea of Switzerland (about 1 cubic mile). The range of volume among the large lakes is enormous, from a lower limit of 5 cubic miles to an upper one of 6,300 cubic miles in Lake Baikal, Siberia. An appreciation of this volume may be gained from the realization that Lake Baikal alone contains nearly 300 cubic miles more water than the combined contents of the five North American Great Lakes. These Great Lakes loom large on a map, but their average depth is considerably less than that of Baikal.

For comparison purposes, here are some of the world's large freshwater lakes (in terms of water volume): Dubawnt, Canada; and Tutigting, China (about 6 cubic miles each); Leman, Switzerland (about 12 cubic miles); Vanern, Sweden (about 35 cubic miles); Nipigan, Canada (about 150 cubic miles); Great Bear, Canada (about 670 cubic miles); Superior, U.S. and Canada (about 3,000 cubic miles); Nyasa, Africa (about, 3,200 cubic miles); Tanganyika, Africa (about 5,000 cubic miles); and Baikal, Siberia (about 6,300 cubic miles).

Saline lakes are roughly equivalent in magnitude to freshwater lakes. Their total area is about 270,000 square miles, and their total volume is about 25,000 cubic miles. The distribution, however, is quite different. About 19,240 cubic miles (75 percent of the total saline volume) is in the Caspian Sea, and most of the remainder is in Asia. North America's shallow Great Salt Lake is comparatively insignificant with about 7 cubic miles.

Rivers and Streams

Rivers and streams are next in the water budget calculations, and here we need to differentiate between the actual amount of water present at any given time in river channels and the amounts that are discharged by the rivers. It has been estimated that the total amount of water physically present in stream channels throughout the world at a given moment is about 500 cubic miles, a small fraction of the world's fresh surface water supply and only a little more than one thousandth of the world's total supply.

To get a better perspective of the relative importance of large and small rivers in maintaining continental water balance, consider some statistics on the amounts of water that flow or discharge out of rivers. The Mississippi, North America's largest river, has a drainage area of 1,243,000 square miles (about 40 percent of the total area of the 48 conterminous states) and discharges at an average rate of 620,000 cubic feet per second. This amounts to some 133 cubic miles per year and about 34 percent of the total discharge from all rivers of the United States. The Columbia, nearest competitor of the Mississippi, discharges less than 75 cubic miles per year. Relatively speaking, the great Colorado River is a watery dwarf, discharging only about 5 cubic miles annually.

On the other hand, the Amazon, the largest river in the world, is nearly 10 times the size of the Mississippi, discharging about 4 cubic miles each day or some 1,300 cubic miles per year -- about 3 times the flow of all U.S. rivers.

Africa's great Congo River, with a discharge of about 340 cubic miles per year, is the world's second largest. The estimated annual discharge of all African rivers is about 510 cubic miles.

Measurements of only the few principal streams on a continent afford a basis for reasonably accurate estimates of the total runoff item in a continental water balance. The small streams are important locally, but they contribute only minor amounts of the total water discharged. Thus, it is possible to estimate the total runoff of all the rivers of the world even though many of them have not been measured accurately. It is calculated that 97 principal rivers of the world discharge about 4,980 cubic miles of water yearly. The estimated total from all rivers, large and small, measured and unmeasured, is about 8,430 cubic miles yearly (about 23 cubic miles daily).

The figure of about 500 cubic miles --the amount estimated to be present in river channels throughout the world at any given moment--is, however, suitable for entry in the world water inventory.

The Atmosphere

The final item in the world's water budget is the atmosphere, the gaseous ocean that clings to the Earth's surface by gravity. In view of the total precipitation that falls on the surface of our planet in the course of a year, one of the most astonishing world water facts is the extremely small amount of water in the

atmosphere at any given time. Consider, for example, that the volume of the lower 7 miles or so of the atmosphere--the realm of weather phenomena--is roughly 4 times the volume of the world's oceans. But the atmosphere contains only about 3,100 cubic miles of water (about one-
one hundredth of a percent of the world's total supply), chiefly in the form of invisible vapor. If all this vapor were suddenly condensed and then precipitated from the air onto the Earth's surface, it would form a layer only about 1 inch thick.

Powered by the sun's heat and energy, together with the force of gravity, the hydrologic cycle keeps the world's water moving; essentially there results a key balance--what goes up comes down. In the natural cycle, there occurs a three-way action that allows the total replenishment of water to the sky, sea, and Earth. It starts with a process whereby water vapor rises into the air from oceans, lakes, forests, fields, plants, and animals the world over (evaporation). This water vapor then develops, by cooling, into visible moisture in the form of clouds or fog (condensation). Finally, the cycle of replenishing is completed by the return of the water to the land and sea in liquid or solid form (precipitation).

As a cycle, the global water system has neither beginning nor end; but from man's point of view, the oceans are the major source, the atmosphere is the deliverer, and the land is the user. In the cycle, there is no water lost or gained; but the amount of water available to the user may fluctuate widely because of variations at the source or, more usually, in the delivering agent. In the geologic past, large alterations in the cycle roles of the atmosphere and the oceans have produced deserts and ice ages across entire continents. Even now, small fluctuations of the local patterns of the hydrologic cycle produce floods and droughts.

On the average--about once every 12 days or so--the water in the air falls and then is replaced. Once fallen, water may move swiftly to the sea in rivers or may be held in glaciers for several decades, in a lake for 100 years, or in the ground from a few years to thousands of years depending upon how deep the water goes. Or, the water may evaporate almost immediately. Regardless of how long the water is delayed, it is eventually released to enter the cycle once more.

About 102,000 cubic miles of water rise into the air annually. Of this amount, about 78,000 cubic miles fall directly back into the oceans. Streams and rivers collect and return to the oceans some 9,000 cubic miles of water including a large quantity that has percolated down into the ground and that, as groundwater, moves slowly to natural outlets in the banks and channels of rivers. This movement of groundwater into a river "feeds" the river, maintaining its flow even when precipitation is scarce throughout the basin drained by the river. The remaining 15,000 cubic miles of water soaked into the ground and, principally as soil moisture, maintain plant and animal life. The water ingested by living organisms ultimately is returned to the air again through evaporation, excreta, or perspiration. Once more there is a balance of water intake and outgo.

In the conterminous (48) United States, it has been estimated that about 1,420 cubic miles (about 1,560 trillion gallons of water or equivalent to about 30 inches of rain) fall annually as rain, sleet, and snow. Of this, about 995 cubic miles (about 1,100 trillion gallons) evaporate into the atmosphere. Another 380 cubic miles (420 trillion gallons) flow to the seas as surface runoff, and about 45 cubic miles (about 50 trillion gallons) of groundwater are discharged directly to the seas. Recent rough estimates by federal hydrologists indicate that there is a total of about 53,400 cubic miles (58,740 trillion gallons) of groundwater in storage in the United States.

A Drumful of Water . . .

If we let a 55-gallon drum, filled to the brim, represent the world's total water supply, then . . .

' the oceans of the world would total 53 gallons, 1 quart, 1 pint, and 12 ounces;

' the icecaps and glaciers would total 1 gallon and 12 ounces;

' groundwater would add up to 1 quart and 11.4 ounces;

' the atmosphere would contribute 1 pint and 4.5 ounces;

' freshwater lakes would add up to half an ounce;

' saline lakes and inland seas would total slightly more than a third of an ounce;

' soil moisture and vadose water would total about one-fourth of an ounce;

' and the rivers of the world would measure only one one-hundredth of an ounce, less than one one-millionth of the waters on the planet.

Global Water: The Challenge

Water everywhere indeed! But while the water cycle balances what goes up with what comes down on a worldwide basis, no such reciprocity exists for individual areas -- a blessed circumstance for some regions and often a disastrous occurrence for others. Simply stated, nature does not always provide the amount of water needed everywhere, when needed, nor with the desired quality. And adding to the fickle ways by which water is distributed through the natural cycle are the complications posed by the spread of human population and activities. With about 97 percent of all water stored in the oceans, and with most of the remainder frozen on Antarctica and Greenland, man must get along with the less than 1 percent of the world's water that is directly available for freshwater use.

Thus, water is a global concern; the water cycle recognizes no national boundaries. Man's future success on this planet may well hinge on the degree to which nations join to cooperate effectively in the conservation and wise development and use of water.