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ABSTRACT

This report deals with the importance of water to life. The physical characteristics of water, its distribution, and a number of current water-related problems are examined. The issue of water management is discussed, along with the ways water is made available for our many uses in life. The introductory essay, "Water in the Global Environment," contains the following sections: (1) "Introduction"; (2) "Basic Water Facts"; (3) "Issues of Water Quantity"; (4) "Water-Related Hazards"; (5) "Issues of Water Quality"; (6) "Water Resources Management"; (7) "Conclusion"; and (8) "References." Learning activities are included for grades 7-9, grades 8-10, and senior high-college. A selected resource list also is included. (EH)

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Water in the Global Environment

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by
Marvin Waterstone, PhD
University of Arizona

With Learning Activities by

Linda Beckham
Martha Bock
Marci Smith

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Water in the Global Environment

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Introduction

It is a rather obvious fact that water is one of the most precious of the world's natural resources. Without it, life itself would not be possible. While water is abundant in an absolute sense, the provision of water in sufficient quantity and quality is an unending task for many individuals and for water managers around the world. The ways in which water is made available for the many activities dependent upon it will be one of the main topics of this paper. However, before turning to this issue of water management, it is important to examine some of the physical characteristics of water, its distribution, and a number of current water-related problems.

Basic Water Facts

The Distribution of Global Water

While the Earth's surface is approximately 70 percent water, we must consider in more detail how much of that water is actually available for use as a resource. Table 1 shows the distribution of the Earth's water. As the table shows, nearly all (over 97 percent) of the water on our planet is found in the oceans. For most practical purposes (e.g., for drinking water, irrigation, or industrial uses) this water is not suitable. The next largest portion (almost 2 percent) of the Earth's water occurs in frozen form, and again for most purposes is not easily available.

In fact, as Table 1 illustrates, 99.3 percent of all the water on the planet is either in the oceans or in frozen form. This means that only 0.7 percent of Earth's water is in the form of fresh, liquid water. The availability issue is further complicated by the fact that of this small percentage, only half is found on, or near enough to the surface to make it readily accessible and economically available.

Because of significant geographic variations in precipitation, evaporation, and wind patterns, water resources are very unevenly distributed around the globe. It should be evident that the distribution of water supplies will not always match the distribution of population and water needs. Therefore, a great deal of the activity of water managers is consumed with addressing just this issue.

If it were not for the fact that fresh water is constantly being replenished through the operation of the hydrologic cycle, we would quickly run short of needed supplies. The operation of this fundamental process is described briefly in the next section.

The Hydrologic Cycle

The amount of water on Earth is finite. That is, we have a fixed amount on the planet, and that amount remains constant. However, the water that is here moves around a great deal, and while doing so it also frequently undergoes changes of state. Sometimes we find water as a liquid, sometimes as a gas (water vapor) and sometimes as a solid (ice).

This constant movement and changing nature of our water resources is described by a process called the hydrologic cycle, which is shown in Figure 1 on page 4.

As Figure 1 shows, the water on the earth is constantly cycling from the oceans, through the atmosphere, and over the land. The hydrologic cycle represents the primary mechanism by which water is redistributed over the globe.

The hydrologic cycle begins with solar radiation heating up water molecules at the ocean's surface. If heated sufficiently, this water will evaporate (change to the gaseous, water vapor, state) and enter the atmosphere. As water vapor rises, it cools, condenses (i.e., returns to the liquid state) and forms clouds. As water drops become heavy enough, they fall to

Table 1

Distribution of Global Water

Location	Percent of Total
Oceans	97.5
Glaciers and Icecaps	1.8
Fresh water lakes	0.01
Salt water lakes	0.007
Atmosphere	0.001
Underground	
root zone	0.001
to 2500 ft.	0.3
below 2500 ft.	0.3
Total	**99.9***

**Does not total to precisely 100 percent due to rounding.*

the earth as one of a number of forms of precipitation (rain, sleet, hail, snow) depending, primarily on atmospheric conditions. Only a small percentage (about 9 - 10 percent) of this moisture falls over land; most of it simply returns directly to the ocean.

Of the proportion that falls on land, some becomes available for and is taken up by plants. Some becomes available as surface water, which means lakes and streams. Some sinks into the ground and then reappears as springs or as recharge for streams and rivers. Some of the water that infiltrates the ground surface may remain underground for long periods of time as groundwater in aquifers.

Once water has reached the land surface and has been directed into one of the pathways just described, much of it is evaporated back into the atmosphere. This evaporation may occur directly from lakes or streams, from soil moisture, or through the process of transpiration through the leaves of plants. Much of this evaporated water returns to the Earth's surface through precipitation in other areas.

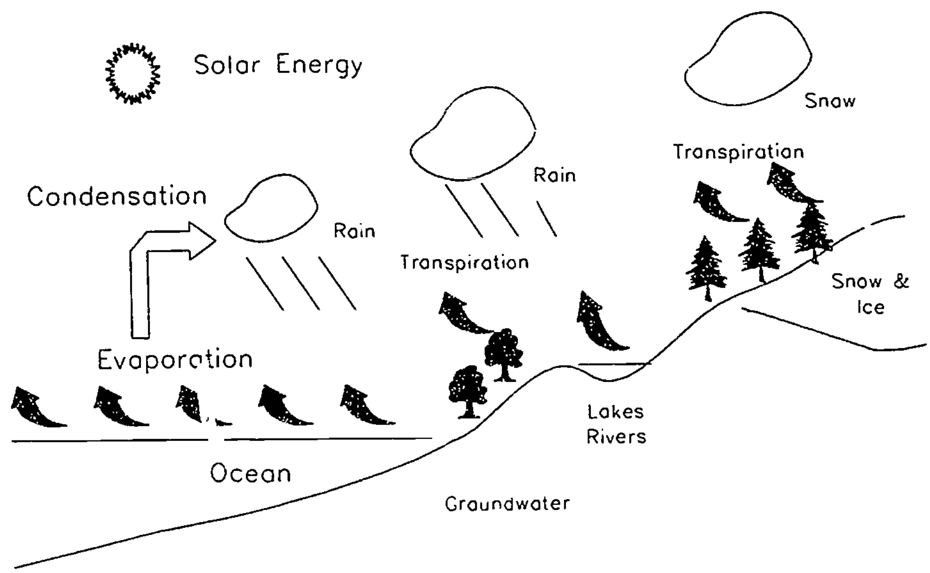
Eventually most of the water which falls on land (the exception is water stored for long periods underground, or in frozen form) returns to the oceans through streams and rivers, directly from groundwater, or through precipitation, and the cycle is completed.

Where this mechanism is inadequate, human intervention is often necessary. However, as we will see below, it is also frequently the case that human intervention in the hydrologic cycle has resulted in severe water problems, including flooding, drought and diminished water quality.

Properties of Water

Why, precisely, is water so important? To answer this question, it is necessary to examine some of the specific characteristics of water that make it unique, and therefore extremely

Figure 1
The Hydrologic Cycle



precious. For present purposes, these characteristics can be divided into three categories: biological, physical, and chemical.

Biological Characteristics—First of all, water is necessary for life as we know it. Human beings, for example are 65-70 percent water. Most of the plants that we use for food are between 85 and 90 percent water (by weight). In addition, without water not only would we dry up as organisms, but there would be tremendous temperature fluctuations that would make the planet largely uninhabitable.

Physical Characteristics—Water is the only known element which exists in all three states (gas, liquid and solid) at temperatures which normally occur on the Earth's surface. Because of this property, it is easily stored and transported around the planet, and is found nearly everywhere. This characteristic, along with water's physical properties, accounts for its wide diversity of roles in earth-shaping activities.

Chemical Characteristics—Water has an unusual molecular structure, consisting of two hydrogen atoms and one oxygen atom, held together by a strong chemical bond. Each water molecule is asymmetrical and each end is electrically charged. Because of these characteristics, water molecules can easily "squeeze in" between molecules of other materials. These characteristics account for the great dissolving property of water, and for the fact that water is sometimes referred to as the "universal solvent." Given enough time, water can dissolve just about any substance. There are many examples of this activity on the Earth, and some are quite dramatic (e.g., Carlsbad Caverns).

Issues of Water Quantity

Of all the issues related to water, probably the most long-standing and prevalent is the issue of adequate supply. As discussed above, the amount of water on the planet is abundant. This abundance is absolute (i.e., the Earth's water supply is inexhaustible), but in particular places at any given time water may be in short supply relative to demand. Posing the issue in this way leads to three possible approaches to assuring adequate supply. The first is to increase deficient supplies. The second is to somehow lower demand. And the third is through a combination of these. The specifics of these approaches will be discussed in this section.

Obtaining Additional Supplies

For millennia societies have been developing technological means to augment inadequate water supplies. In many cases this has been accomplished by attempting to alter some component of the hydrologic cycle. For example, much effort has been devoted to such activities as damming rivers to create reservoirs, changing the flow and direction of streams, pumping groundwater, altering vegetation in watersheds. Let us look at a few of these options in more detail. The discussion of these approaches is not meant to be exhaustive, but will serve to illustrate the variety of techniques that people have employed to assure themselves of reliable water supplies.

Water Development Projects—Some of the very earliest human engineering works were aimed at providing water. The earliest recorded dam was probably constructed over 5,000 years ago in Egypt. Since that time this technology has become extremely widespread, with dams (and their accompanying storage reservoirs) now a common mechanism for evening out erratic supplies of water. Of course, dams are also used for other purposes than just water supply, including hydropower production, flood control and recreation.

A feature which frequently accompanies damming is water *diversion*. In general, diversion refers to the activities which actually remove water from a streambed. By creating a reservoir, and then by constructing new channels it is possible to direct water to locations where its use is believed to be more advantageous.

Such water development activities produce a number of benefits, as well as several significant types of costs. On the plus side, water development can remove some of the uncertainty usually associated with fluctuating supplies. The creation of storage reservoirs allows for longer-range planning, and more flexibility for societies. By lowering dependence on what the natural system supplies, it is possible to stabilize water resources over long periods.

However, such developments also bring a variety of costs and undesirable effects. One of the most immediate effects, of course, is the inundation caused by the reservoir itself. In many cases, the lands that are submerged may have been inhabited by people. In almost all instances, such areas are home to indigenous plants and animals. In the former, cultural artifacts and/or sacred landscapes may be lost; in the latter much valued habitat may be destroyed. In addition to inundation, building dams and creating reservoirs produces effects on: 1) local and regional hydrology (e.g., changes in streamflow and flooding characteristics, increased evaporation, and alteration of the recharge rates to groundwater aquifers); 2) soil and landforms (e.g., reduction of downstream silt and nutrients, triggering of earthquakes, and changes in erosion patterns); 3) local and regional weather (including temperature, humidity, precipitation and winds); and 4) biological communities (e.g., through changes in nutrient loads in streams, changes in water flow patterns, and changes in climate).

Of course the evaluation of these effects entails making tradeoffs. Decision makers must ask themselves and their constituents: how valuable are the benefits of the water supplies obtained, and how do these benefits compare with the costs of water development? Also, alternatives to traditional dam and reservoir systems must be considered when making such calculations.

Weather Modification—One long-pursued option is the series of activities known collectively as weather modification. In its most commonly understood sense, weather modification refers to rainmaking. For millennia, humans have sought ways to control or influence the weather to produce desirable conditions. In arid regions, particularly, this activity has been directed at increasing rainfall during critical periods. People have used prayers, sacrifices (human and animal), loud noises, and rainmakers with all sorts of devices (chemical, electrical, etc.) to induce the skies to produce needed moisture.

In recent years, more scientific approaches to rainmaking have been developed and tried. Much of this activity has revolved around the practice of cloud seeding. To understand cloud seeding, it is important to know a little about the process of precipitation. In order for rain drops to form and fall, two conditions are necessary. The first is an adequate supply of moist air rising in the atmosphere so that it cools to the point where the air becomes saturated. The second is the presence of particles such as dust, salt or other materials (called *condensation nuclei*) onto which water molecules can adhere and form drops sufficiently large to fall to the earth. If only one of these conditions exists, it is unlikely that precipitation will fall in significant amounts.

Modern cloud seeding techniques try to take advantage of this knowledge. In general terms, cloud seeding attempts to place additional condensation nuclei into appropriate clouds in order to increase the number and size of water droplets, and thereby increase the amount of precipitation. Some efforts are aimed at increasing rain at a particular time and place, while others have been directed at increasing winter snowpacks, and therefore spring runoff.

Thin clouds (stratiform) are not good candidates, since they usually contain insufficient moisture. Therefore, cumuloform clouds are most often selected. These generally contain adequate supplies of moisture. The material that is used as condensation nuclei must be able to attract and hold water molecules efficiently. One substance that has been used for this purpose is silver iodide. Particles are dropped into clouds from airplanes or shot into clouds from the ground, with the hope that these additional condensation nuclei will result in more precipitation.

Has cloud seeding been successful? The results of the past four or five decades of research are uncertain at best. First there is the problem of determining whether the cloud seeding activity produced any effect at all. This is not as easy as it might seem. The conditions under which precipitation falls naturally are highly variable. It is extremely difficult to predict the amount and nature of precipitation that might occur at any particular place even without attempts to modify the weather. Therefore, being able to determine if additional or lower precipitation has occurred is nearly impossible. Put another way, it is very difficult to establish what the precipitation would have been like without the cloud seeding, and therefore it is not really possible to attribute some proportion to "natural" precipitation and the rest to seeding.

Even if cloud seeding were demonstrated to be effective, many social, political and legal problems would remain. One nagging concern has been over the so-called "theft of downwind water." Some have argued that if cloud seeding operations are successful, and cause additional precipitation to fall in a particular location, this might deprive downwind areas of water that would have fallen on them. The evidence is not conclusive on this point either way, but the public perception of this possibility has raised problems.

A second, non-technological issue concerns the ownership of newly created water supplies. In many areas, for example in the western United States, virtually all surface water supplies are controlled through a system of water rights. If new supplies are produced through weather modification, who would own them? How would they be distributed? These are difficult legal and political issues and have not yet been addressed adequately.

Yet with all the problems (both technical and social) weather modification continues to be attractive as a potential solution for inadequate water supplies. Research continues in this area, and humanity's dream of controlling the weather persists.

Desalination—Another approach to obtaining additional water which has a very long history is the conversion of salty or ***brackish*** (a mixture of fresh and salt water) water into fresh, usable supplies. Recalling that over 97 percent of the planet's water supplies are in the ocean, it is not at all surprising that saline waters have long been viewed as a potential supply. In recent decades, technologies for extracting fresh water from saline sources have moved from theoretical possibilities through pilot testing to practical, full-scale facilities. Currently, desalination plants are operating around the globe, and employ a variety of techniques to convert salt water into fresh.

There are three main categories of approaches for desalinating water. Mather (1984) identifies these as: 1) processes which utilize state changes of water (e.g., distillation or freeze separation); 2) processes which rely on the surface properties of membranes (e.g., reverse osmosis); and 3) processes which involve ion-exchange.

By far, distillation is the most widely employed technique in large-scale operations. However, the selection of a particular technique depends, among other factors, upon the characteristics of the water to be desalinated, the end uses to which the water will be put, energy and other costs, and the options available for dealing with waste products.

Desalination attempts to take a potential resource (seawater or other saline sources) and convert it into an actual resource. In areas where supplies of fresh water are limited, but where saline water is plentiful and accessible, desalination is becoming increasingly attractive. This will continue to be the case as the efficiency of technologies increases and the costs come down. Of course, as with any approach to obtaining adequate water supplies, the costs of desalination must be compared to the costs of alternatives.

Watershed Management—A final alternative for increasing water supplies which will be described briefly is ***watershed management***. This term generally refers to alterations of the earth's surface or vegetation in order to increase usable water supplies. Again, a variety of techniques are evolving to achieve these purposes. Some approaches attempt to increase water infiltration and percolation to recharge groundwater aquifers, some to increase the yield to streams and rivers, and others to increase or maintain water in snowpacks.

Since much water is commonly lost to a region through ***evapotranspiration*** (the process by which water escapes through openings in the leaves of plants during photosynthesis), one management technique is to reduce the amount of vegetation, or to replace plant species with high transpiration rates with varieties that transpire less.

A second general set of techniques involves manipulation of the land surface itself, either to increase infiltration in order to recharge groundwater aquifers, or to increase surface runoff for collection in streams and reservoirs. In the first case, the intention is to make modifications on the land surface (e.g., contour plowing or terracing) that increase the time water is held on the soil. In the latter case, the land surface may be modified in ways that make it more impervious, and therefore increase overland flow and surface runoff. Often, such activities have been called "water harvesting," and can significantly increase water supplies.

In either case these practices frequently have implications which go beyond simply the effects on water supply. For example, terracing and contour plowing may reduce the magnitude of floods, while creating impervious surfaces may increase the velocity of flood waters in some areas.

Alterations of watershed areas still require a great deal of study to understand the precise relationship between changes on the land surface and/or vegetation and effects on water supply. And because important watersheds are usually the site of other commercial activities (e.g., forestry and timbering) or significant habitat for plants and animals, any manipulations must be evaluated in the context of multiple (and often competing) uses. This is a point to which we will return in the final sections of the paper.

Conservation and Use Efficiency/Water Reuse

All of the techniques just described have as their goal the acquisition of new supplies of water. An alternative set of approaches to the problem of adequate supplies is to manage the demand for water, and/or to use those supplies that already exist in a more efficient way. These approaches will be examined in this section

Water Conservation and Use Efficiency—In some sense, conservation represents the least expensive alternative for assuring a reliable water supply, at least in the developed countries. In many parts of the developing world, water is already used as efficiently as possible.

A first question that must be addressed relative to water conservation is: "What will motivate people to use water resources as efficiently as possible?" Or, to pose the question another way: "Why would anyone waste such a precious resource?" The answer, in part, is suggested by the question. In order to use water wisely, people must be convinced that it is a precious resource. We all know this at some basic level. But in many parts of the world, particularly where water is bought and sold, this knowledge is contradicted by the fact that water is generally not priced as though it were precious. So one mechanism to increase conservation and efficient use is to raise the price of water so that wasteful use is penalized rather than encouraged. Of course such an approach raises many questions of fundamental fairness. Should access to an adequate supply of clean water be a right of every person? If this is the case, how can high prices for water be justified? Indeed, how can the practice of buying and selling of water be justified? The resolution of such issues rests, in part, on determining basic water needs for individuals, and differentiating these basic needs from other uses of water which represent wants or desires. The basic needs should be assured, while the wants and desires should be fulfilled according to individual and societal priorities.

However, once people are convinced of the need for water conservation, there are two basic approaches that may be taken. The first includes a set of conservation technologies and devices. These include everything from low-flow showerheads and low water-use toilets for residences to drip irrigation and laser-levelled fields for agriculture and water-saving devices for industry. There are many such devices available which have demonstrated their effectiveness in reducing water use. They merely have to be adopted by water users and water supplies will increase (i.e., through the water thus saved).

The second approach does not involve technological solutions, but focuses on changes in behavior and practices. Again, such approaches may be used in a residential setting (e.g., shorter showers, using a broom to clean sidewalks rather than a hose, etc.), in agriculture (e.g., changing crops, changing growing seasons, etc.), or in industry (e.g., by altering production processes or product lines). As with the technological approach, these practices can save significant quantities of water, and thereby defer or eliminate the need to obtain additional supplies. It is a matter of convincing people that such conservation behaviors are both necessary and desirable.

Water Reuse—A final approach, and in many areas this has literally been the approach of last resort, is the reclamation and reuse of sewage water. While this is becoming a more prevalent practice, several considerations still impede its widespread adoption. This is especially the case when reused water is being contemplated for drinking purposes. The first impediment is the cost. The cost is primarily related to the extent of the water treatment that is necessary, and depends on the initial quality of the water to be reused, the treatment method(s), and the required quality for the end use of the water. It should be evident that the lower the initial quality of the water, and the higher the end-use quality required, the higher the costs will be.

A second significant impediment is aesthetic and perceptual. Many people simply do not find this practice acceptable. Although in an absolute sense, we reuse our water resources continually, and despite the fact that societies have been reusing their own sewage for thousands of years, the practice of reclamation and short-term reuse has not gained widespread public support, particularly in the Western world. It is possible that this sentiment will change, as new sources of water become increasingly difficult or expensive to obtain, and as water treatment technologies continue to improve.

In the meanwhile, it is possible to reclaim wastewater and apply it to uses other than drinking supplies. This is occurring to a significant extent in many areas of the globe. Reclaimed sewage has long been applied to irrigate crops. However, as we have discovered over time, this practice has led to serious health-related problems in many situations. If not properly treated, the pathogens in sewage water can be transmitted to the crops and then taken up by people or animals when the crops are consumed. However, it is possible to apply reclaimed sewage water to non-food or non-feed crops (e.g., cotton) and derive significant benefits of both moisture and fertilizer.

In addition to applications in agriculture, many industrial processes (e.g., cooling) are able to use supplies that are below drinking water quality, and therefore represent another outlet for reclaimed sewage water. For many industries this water supply represents a cost-effective alternative to finding new sources of water.

Finally, many municipalities have begun to use reclaimed water for irrigating parks, golf courses, road medians and other public open spaces. Again, reclaimed water may be highly competitive with other water sources.

In the future, especially for many urban or industrial regions, reclaimed water may become the most readily available, economical way to increase water supplies. We need to be able to understand the reasons that people will accept reuse of water if it follows the usual chain: use, treatment, discharge into stream or aquifer, treatment, and reuse; but are resistant if the intermediate step of discharge into streams or aquifers is omitted. People living at the lower end of the Mississippi River use water that has been used, discharged and treated several times before it reaches their tap, and this seems to be perfectly acceptable. And yet if asked, most would find reuse directly from a sewage treatment plant to be undesirable.

Summary

We will return to a few of these issues shortly in the section on water quality. However, for the present discussion let us sum up by indicating that in the future new sources of water will be increasingly difficult and expensive to acquire. New water development, weather modification, desalinization, watershed management, and other techniques (e.g., interbasin water transfers, use of evaporation suppressants, towing of icebergs, etc.) are probably going to play a decreased role. This is especially true as we begin to calculate all of their costs (including direct and indirect effects on the environment, impacts on cultural and aesthetic values, as well as monetary). This means that the approaches which concentrate on managing demands, increasing water use efficiency, and reusing supplies will take on added importance in years to come. We still have many questions to resolve regarding these approaches. Most of the issues are political, social, and economic in nature, rather than technological. However, these are the issues that are often most difficult to address satisfactorily.

Water-Related Hazards

In addition to the common vagaries related to water supplies, there are two conditions that are especially troublesome. The first is the problem of too much water at a particular location at a particular time: flooding. The second is the persistent lack of water· drought. It is worth devoting a little attention to each of these phenomena, since they prove to be so costly each year over the Earth.

Floods

Flooding is a common and natural occurrence. It takes place whenever a stream overtops its banks. It also takes place whenever ocean waters invade areas outside the normal tidal zone. For the most part, these occurrences would go unremarked if people and property were not in the areas of inundation. This is not to say that floods do not produce significant impacts on the non-human environment. However, it is only when humans are affected that much attention is paid to flood events. In fact, in some fundamental way, overbank conditions only produce a hazard when they interact with human systems.

Unfortunately this happens rather frequently. Riverine floodplains and coastal lowlands historically have been highly attractive places for human settlement. Thi ontinues to be the case. Such areas offer many advantages. Floodplains, for example, tend to be flat, fertile, and aesthetically pleasing. They also offer ready access to transportation and energy (either direct use of the water or to produce electricity). If it were not for this extensive human habitation, the periodic overbank conditions would only represent normal processes.

Many approaches have been taken to reduce the toll of flooding. Some (weather modification, watershed management) focus on preventing floods from occurring or reducing their magnitude. Others (levees and seawalls, dams, channelization efforts) are aimed at preventing or reducing the inundation in areas of human settlement. Still other approaches are aimed at saving lives either in the short term (warning systems), or in the longer term (land use management to prevent settlement in flood prone areas) Finally, some approaches (insurance and disaster relief) are aimed at compensation and loss spreading if flooding occurs and causes damage.

Despite all this attention floods continue to be a major problem. Worldwide, tens of thousands of people are killed, and billions of dollars of property are destroyed annually. The trends differ between the developed and developing nations. In the former the trend is toward fewer deaths, but greater property damage, while in the latter the reverse is the case. These differences can be explained in part by patterns of settlement and investment, and in part by the accessibility of technological mitigation strategies.

Droughts

At the other extreme of the water supply spectrum is the problem of droughts. As in the case of floods, extended periods of decreased precipitation are common, natural occurrences in many parts of the world. It is only when these conditions impinge upon people and their way of life, that these otherwise natural conditions begin to be problematic (at least from a human perspective).

However, unlike flood conditions, it is sometimes extremely difficult to state with precision when dry conditions become a drought. Often it is also difficult to say when a drought has ended. The beginning and ending of droughts is related to the interaction of changes in the physical systems (e.g., temperature, precipitation, evapotranspiration, etc.) and the human systems' ability to accommodate such changes without dislocation.

Droughts affect both rural and urban areas, but in different, and sometimes highly connected, ways. In rural areas droughts have immediate impacts on crops and livestock. Depending on the length and severity of dry conditions, farm incomes may be reduced, indebtedness may increase, and in extreme circumstances (e.g., during the Dust Bowl in the United States in the 1930s), farms may be abandoned. Such impacts in rural areas may translate into effects elsewhere. For example, food and fiber prices may rise, increased unemployment on farms may affect regional economic conditions, and these conditions, in turn may alter regional, state and national policies concerning subsidies, foreign trade and other issues.

In urban areas, the impacts of drought are somewhat different. Residents of cities are somewhat insulated from the vagaries of nature. Since urban areas draw on many sources of food and fiber from all over the Earth, it is possible that drought conditions in particular rural or agricultural areas will not produce much impact. Substitute sources for urban needs can often be found. However, one way in which urban areas can be affected significantly by prolonged periods of dry conditions is the vulnerability of their water supplies. Usually urban areas do not have ready substitutes for this vital resource. Water systems in areas where periodic droughts are possible usually include some storage capability to get the city through dry periods. However, if droughts are long enough, even these stored supplies can be depleted or severely stressed.

The strategies for dealing with droughts differ in important ways between developed and developing nations. In the developed world, response tends to be more technological in orientation. For example, some areas may seek to augment their supplies (either temporarily or over the longer term) through such mechanisms as desalination or weather modification, the use of reclaimed sewage, or the construction of new diversion and storage works. There also may be attempts to manage demand (particularly in urban areas) through regulatory programs that restrict water use, or through incentive or voluntary programs to promote conservation. In agricultural sectors, it is possible to alter cropping patterns (in terms of timing, crop types, inputs of fertilizer, or the extent of agriculture).

In many areas of the developing world, droughts also pose extremely difficult problems. Again, because of a lack of technological approaches for ameliorating the impacts of droughts, the range of strategies is somewhat more limited than in developed nations. Despite this, many inhabitants of arid regions have evolved a set of mechanisms for coping with droughts. Depending on the duration and severity of dry conditions, any or all of the following approaches may be employed: extension of planted area (to compensate for decreased yields), alteration of crop mixture (more use of drought-resistant types), purchases of grain or use of indigenous famine foods (i.e., native species), migration from rural areas on a temporary basis to find wage labor, production of items for sale, sale of personal assets, mobilization of social networks for aid, or, under very difficult conditions, permanent outmigration.

Summary

Flooding and droughts represent the extremes of water supply problems. However, in between these conditions, a wide variety of supply issues confronts water managers all over the world. Maintaining reliable supplies in the face of great natural variability presents a substantial challenge to such managers, and their response to such challenges reflects their own creativity and the social, political and economic circumstances in which they labor.

Issues of Water Quality

Providing a reliable supply of water in quantitative terms (i.e., the right amount to meet demands) is only part of the story. In addition, water must be of an acceptable quality. In general terms, a polluted water body (whether a lake, stream, ocean, or groundwater aquifer) is one which has physical, chemical or biological properties which interfere with its intended use or uses. These physical, chemical and biological properties are usually present in water bodies in acceptable concentrations. They become pollution when their concentrations are no longer suitable for particular uses. These statements should make it clear that water quality is a *relative* phenomenon, and depends on the desired use of the water.

Properties of Water Quality

Several characteristics of water are commonly considered in the assessment of water quality. Some of these relate to the aesthetics of water, some to the abilities of water to support aquatic plants and animals. and some to the human health effects of water bodies. These properties, which will each be discussed briefly in the following sections, include: 1) turbidity; 2) color; 3) odor; 4) temperature; 5) the presence of gases and solids; and 6) biological organisms. We will consider both the conditions which affect each of these properties, as well as the effects which may be produced when the quality of these properties is impaired. These properties also interact, and where these interactions are important the discussion will address them.

Because the emphasis here is on water as a human resource, fresh water is the most significant concern. So, although ocean pollution is a significant problem worldwide, in this paper, we will focus only on freshwater quality. Also, the discussion of water quality properties will emphasize surface as opposed to groundwater conditions. Groundwater quality will be discussed below.

Turbidity—This term refers to the degree of opaqueness of water, and is inversely related to the degree of light penetration into the water body. High turbidity is the result of increased loads of suspended and deposited sediments in streams and lakes. The turbidity characteristics tend to differ between streams and lakes. In the former, many solids tend to remain in suspension, while in the latter these materials tend to settle out as bottom deposits.

These sediments may come from a wide variety of natural and human activities, including floods, landslides, construction, deforestation, plowing and other agricultural activities, and mining, to name just a few. Controlling these activities is the key to reducing undesirable levels of turbidity.

Highly turbid waters suffer from decreased light penetration. This, in turn, may affect many aquatic organisms by directly altering relationships in the aquatic food chain. For example, the algae which form the base for many food chains, may be unable to carry on photosynthesis. The organisms which depend on this algae, either directly or indirectly, are then also affected.

In addition, high turbidity has effects on public water supplies, hydroelectric plants, industrial processes, and harbors and channels. Many billions of dollars are spent each year combatting the effects of turbidity and sedimentation.

Color—Color is an important indicator of the productivity (i.e., biological vitality) of a water body, as well as an important perceptual or aesthetic property of water. As with turbidity, the color characteristics of lakes are somewhat different than streams. Lake color can vary considerably and depends primarily upon the materials contained in the lake, the size, shape and temperature of the lake, and the water source. A highly productive lake (i.e., one which contains much biological activity) tends to be grayish blue or sometimes yellow in color. Less productive lakes tend toward blue or blue-green shades. A completely pure water body would absorb all light and appear black.

Streams, in general, do not vary in color as much as lakes, especially during non-flood periods. This is due primarily to the amount of mixing which goes on in flowing water. In their upper reaches, many streams do not contain much organic material, and therefore, tend to appear clear. Moving downstream, there is generally more organic matter, and streams turn brown. The color of a stream might also depend on the accumulation of leaves (causing a very dark hue), or on surface algae (producing a green cast to the water). During flood periods, streams may pick up colors which reflect the area's soils and geology.

In addition to its use as an indicator of aquatic productivity, color may also be an important perceptual cue to water users. Water bodies that might otherwise be perfectly satisfactory, may be deemed unacceptable if they exhibit unusual color characteristics.

Odor—This aesthetic property is another indicator of water quality. As with the color, a bad smell may put a water body off limits, even if it is perfectly adequate on other quality grounds. The odor of a stream or lake is dependent on the biological and chemical materials it contains. Water bodies which receive drainage from industrial sites, urban areas, swamps, agricultural zones and livestock areas tend to become particularly malodorous. We will return to this property in a moment when we discuss dissolved gases in water.

Temperature—Change in the thermal characteristics of water affects directly the ability of aquatic plants to produce oxygen, and the activity of biological organisms. Again, streams and lakes respond quite differently in terms of temperature. Without human interference (i.e., discharges), the water temperature of streams is controlled primarily by solar radiation.

The thermal characteristics of lakes are more complicated than streams. In general, lakes are deep enough to have distinct thermal layers, and the temperature patterns change markedly with seasons (at least in mid- and high-latitude regions). In winter, the temperature in deep waters tends to be relatively warmer than waters near the surface. This leads to the depletion of dissolved oxygen, and decreased biological activities at lower lake levels. When spring arrives, the upper part of the lake waters become dense, and mixing of lake waters occurs.

In summer, the lower layers tend to be colder than the surface layers, and little mixing occurs. Dissolved oxygen may be depleted at all depths, and biological activity may decrease. This can be exacerbated by activities which alter the water temperature.

Temperature alterations affect the ability of water bodies to contain important gases (especially oxygen). Changes in temperature also affect the ability of aquatic animals to reproduce and survive, often leading to new mixes of species in a lake or stream. In many cases, such temperature changes need not be large, as many species are extremely sensitive to very small changes in temperature. Also thermal pollution (usually referring to the increased temperature of a water body) often increases the number of disease-causing organisms, and may decrease the ability of various species to withstand diseases.

The causes of thermal pollution are many, but chief among them are urbanization and industrialization, changes in river channels, the construction of reservoirs, and cooling processes associated with the production of energy. Many of these are amenable to low-cost control (e.g., through the construction of cooling tanks), but these costs must be compared to the benefits provided.

Dissolved Gases—Several gases are extremely important constituents of healthy water bodies. Others form in water bodies when polluted conditions exist. The most important gas is dissolved oxygen (DO). It regulates the metabolism of aquatic animals, and photosynthesis of aquatic plants. The amount of DO in a water body varies inversely with temperature and salinity (as temperature and/or salinity increase, DO decreases), and varies directly with atmospheric pressure (as pressure decreases, for example with increasing altitude, DO also decreases). So high altitude lakes in summer are more likely to suffer DO depletion.

Oxygen in water generally comes from two sources. The first is oxygen which is mixed into water from the atmosphere by wind, waves or other dynamic processes. The second major source is a by-product of photosynthesis by aquatic plants.

One sign of a polluted water body is a decrease in DO. One way this is measured is through a characteristic termed biological (or sometimes, biochemical) oxygen demand, BOD, which measures the rate at which DO is being used by bacteria and other micro-organisms to decompose organic matter. A high BOD reading suggests that a large amount of organic material is present in the water, often an indicator of water pollution. A low BOD reading means either that the water body is clean, or that the decomposing micro-organisms have been killed, usually by toxic pollutants (which we will address shortly).

A second important gas is carbon dioxide (CO_2), which acts as a buffer to prevent rapid shifts in the pH (i.e., the acidity) of water bodies. Carbon dioxide also helps to regulate biological processes in aquatic plants and animals. In general CO_2 is highest when DO is lowest. In water, the main sources of CO_2 include the respiration of aquatic animals, the contact of water with carbonate rocks (e.g., limestone), the contact of water and the atmosphere, and the bacterial decomposition of organic material.

Two other important gases are methane and hydrogen sulfide. Both of these are produced when organic matter is broken down by bacteria under anaerobic (i.e., without free oxygen) conditions. Methane is odorless, but hydrogen sulfide gives off a characteristic rotten egg smell. The presence of these gases in sufficient quantity is likely to limit the use of a water body severely.

Inorganic Dissolved Solids—Many of these substances, which include carbonates, sulfates, calcium, iron, magnesium, nitrates and phosphates are critical nutrients for aquatic life. If their concentrations become too low, water bodies may become lifeless. However, in sufficiently high concentrations, these lead to increased algal growth, decreased DO, and a process known as *eutrophication*, or water body death.

All of these are naturally occurring substances, and their normal variability in water bodies is dependent largely on the local weather patterns, as well as local soil and geologic conditions. However, their concentrations can also be affected significantly by such human activities as agriculture, construction, mining, urban runoff, and industrial discharges.

Biological Organisms—The final water quality property to consider includes a variety of organisms that can be harmful to human health, as well as non-human species. Taken as a group, these organisms are termed pathogens, which means they are disease-producing. These might be bacteria, viruses, parasites, or any number of others. These *pathogens* are of most concern when they contaminate human drinking water supplies, and for much of the world such problems remain highly significant.

The Changing Nature of Global Water Quality

In the final sections of this discussion we will contrast briefly the water quality issues facing the developing world with those in the more industrialized countries. We will examine the nature of the most salient water quality problems, as well as the measures being taken to deal with these problems.

It is possible to characterize water pollution problems as following a sequential pattern, both globally and in specific countries. Tracing this pattern will help put current issues into a historical perspective.

Prior to the industrial revolution, most water quality problems were rather restricted in their geographical extent. This is not to say that local problems (mainly resulting from the inadequate disposal of human waste) were not severe at times. However, the absorptive capacity of lakes, streams and groundwater aquifers was usually adequate on a regional scale. In more recent times, and particularly during the 20th century, this absorptive capacity has been sorely stressed in many parts of the world.

In the early 1950s, most pollution was largely tied to excessive amounts of biodegradable organic wastes (including pathogens) coming from municipal discharges. The result was severe oxygen depletion in many water bodies, with consequent fish kills and plant death. In the industrialized nations this problem has been addressed to a great extent through the construction of treatment works which remove much of the oxygen-demanding waste from municipal effluent. Such treatment works are costly, and therefore, many of the developing nations have not yet been able to undertake these measures. As a result, this still represents a significant problem in many developing nations.

In the 1960s, eutrophication became a salient issue. As biodegradable organic wastes began to be removed, the problem focus shifted to nutrients (particularly phosphorous and nitrogen), algal blooms and water body death. In the developed countries significant effort went into measures to reduce inputs of these nutrients (e.g., the introduction of low- or no-phosphate detergents). However, in developing nations nutrients are still an important concern, especially from non-point, agricultural sources.

In the 1970s, the emphasis again shifted, and in several directions. For the first time, a widespread concern arose regarding the by-products of industrial processes. Heavy metals (especially lead and mercury), synthetic organic chemicals, and acid precipitates became targets for public interest and policy, particularly among the more industrialized nations.

Also during the late 1970s and early 1980s, the first major attention to groundwater contamination arose. Prior to this time, it was widely believed that groundwater sources were essentially safe. This was generally an accurate assessment. The soil and the intervening ground layers between the surface and aquifers are capable of removing substantial quantities of pollutants. However, by the late 1970s, both the magnitude of contamination as well as the changing nature of the pollutants themselves (i.e., more low-weight, synthetic chemicals) were overwhelming the cleansing capabilities of the natural system. Consequently, widespread groundwater contamination became a salient issue.

The nature and sequence of water pollution generally has followed demographic patterns (e.g., population increases, rural to urban migration, and age trends in populations), as well as industrial and agricultural development activities. Increased public awareness, followed by political and technical solutions have also taken on sequential characteristics which depend on other societal issues and available resources.

As a general way to characterize the current situation, it is possible to classify nations into three categories: 1) highly industrialized nations; 2) newly industrializing nations; and 3) low-development countries (with primarily traditional agricultural economies). Each of these three types displays different water pollution problems.

The most highly industrialized countries (primarily in Western Europe and North America) have followed the sequence just described. The traditional pollution problems (i.e., pathogens, oxygen-demanding wastes, eutrophication) have largely been addressed in these nations, usually through the application of advanced treatment technologies. The primary water pollution issues which remain are those related to synthetic organic chemicals, acidification, and groundwater contamination.

The most vexing pollution problems are occurring in the newly (and for the most part, rapidly) industrializing nations, such as China, India, Brazil, Mexico, Nigeria, Indonesia, and Korea. In such areas the sequence of pollution types is also being followed, but in a much compressed time period. This sequence took as much as 150 years in Western Europe and the United States, which allowed amelioration strategies to be developed as problems became recognized. However, in many of the most rapidly developing nations, this sequence is taking place within 20-30 years. Consequently, remedial measures are failing to keep pace. Very few countries (only 10 out of 60, according to the World Health Organization) in this category have developed adequate legal frameworks to control pollution, and most do not have the necessary financial resources to implement and enforce the few laws which do exist.

The final category includes nations which have not yet begun to industrialize. In these countries water pollution problems tend to be somewhat restricted in scale, and primarily affect urban areas. However, this picture is changing as development activities (especially mining and other forms of resource extraction) begin to increase.

Summary

Access to safe water is almost seen as a basic human right. And yet in many parts of the world, this cannot be assured. As of 1985, the World Health Organization (WHO) estimated that 60 percent of the world's rural population and 25 percent of the world's urban population still were not served by reliable, safe water supplies. The figures for sewerage systems were similar with large segments of the world remaining unserved by adequate sewerage (84 percent of rural residents, and 41 percent of urban inhabitants) (WHO, 1988). Although progress has been made in recent years, there are still many people who are unable to obtain reliable, safe water on a sustained basis. This failure is reflected in the rather startling fact that water-borne diseases still cause an average of approximately 25,000 deaths per day on a global scale (Meybeck, Chapman and Helmer, 1989: ix).

Water Resources Management

In this final section of the paper, I simply want to highlight briefly two of the major issues that are looming on the horizon. Each of these issues presents its own set of problems, challenges and opportunities for water managers.

Sectoral Competition for Supplies

As we have seen it is becoming increasingly difficulty to find or develop new water supplies. We have also noted that the cost of treating water to provide adequate quality is continuing to increase. When these supply side factors are combined with increasing worldwide demand it is easy to see how the problem of competition for limited supplies will present water users and managers with a set of very difficult issues.

Before examining the political and social side of this issue, let us discuss a few pertinent facts. A list of water uses includes: 1) agricultural; 2) municipal (residential and commercial); 3) industrial; 4) power production (hydropower); 5) navigation; 6) recreation; and 7) fish and wildlife habitat. These uses differ in several critical respects. The first difference is the amount of water devoted to each sectoral use. Table 2 shows the distribution of water use among sectors for various countries. The differences reflect the mix of economic activities in each country and the stage of development. On a global scale, agricultural uses account for approximately 80 percent of all water withdrawals.

This brings us to a second difference among uses. Some uses require water to be withdrawn from water bodies. These include agricultural, industrial, residential and commercial uses. Others allow water to stay in the stream or lake. These include recreation, fish and wildlife, navigation and transportation, and hydropower. It should be evident that the uses which require water to be withdrawn compete directly with the so-called "in-stream" uses.

A third important difference among uses is the impact that each produces on water quality, and therefore on subsequent water use. Agricultural use may add fertilizers, pesticides or livestock wastes. Industrial use may add heavy metals or synthetic organic chemicals. Residential and municipal use may add human wastes and materials picked up as water traverses urban areas. Each of these uses has serious water quality implications. Often use in one sector means that water will be unavailable (or extremely expensive if treatment is required) for other sectors.

Such competitive demands must be resolved on the basis of societal priorities. However, determining the criteria upon which such trade-offs will be made is extremely difficult. How can determinations be made regarding the importance of agriculture vs. industry vs. fish and wildlife habitat? How can industrial or other economic development be evaluated relative to the importance of feeding one's population? This last point is extremely salient in many parts of the developing world, where scarce water supplies may in fact be the most significant factor limiting economic development.

One solution in many societies is to let market forces decide. In other words, the sector that can pay the most for water should receive the highest priority for allocations. And yet, many people express concern that some uses which society may value very highly do not yield the financial resources that would allow them to compete for water supplies. This is often the case with fish and wildlife or recreation uses as compared with urban or industrial uses. Resolving such issues will require great ingenuity and creativity on the part of policy makers and water managers.

Water Resources and Global Climate Change

This final issue has received a great deal of scientific and political attention in the past decade, and is worth exploring in some detail. In part this is because the potential impacts are enormous, and in part, because this issue of potential global warming can be viewed as an archetype for an emerging class of environmental issues. In many ways, global warming represents those issues (of which there are several receiving attention presently, and many more to come) which will require international cooperation and political will if they are to be addressed at all, let alone resolved. Global warming also typifies a set of concerns that have long planning horizons, are underlain by great scientific uncertainty, and which will produce widely differing impacts around the globe.

Although there is a lack of agreement among scientists on some of the specific points, consensus is growing within the scientific community that increasing atmospheric concentrations of carbon dioxide (CO_2) and other "greenhouse gases" are leading to an alteration of the earth's climate. While much uncertainty remains regarding the precise nature of these changes, most analysts are now pointing to a warmer climate. On a global scale, this warming is estimated to be in the range of 1 1/2°C to 4°C, with greater warming anticipated at higher latitudes. Changes in other climatic parameters (e.g. precipitation, evapotranspiration, circulation and wind patterns, cloud development, etc.) are also anticipated, although the level of agreement on these other factors is significantly less than that for temperature.

It is clear that any substantial changes in climate will produce important impacts, both direct and indirect. One immediate concern is over the impacts of altered climate on resource systems, particularly on a variety of aspects of water resource systems. It is almost certain that new climate patterns will affect both water supply and water demand patterns. Again, although the precise nature of these impacts is unclear, water planners and managers will require guidance in order to anticipate these changes and accommodate to them.

At present, most of our information regarding possible climate change is derived from large-scale, general circulation models (GCMs). While these models are somewhat useful for diagnosing climatic trends at large spatial scales, their gross resolution limits their application to more regional and local scales. However, it is at these latter scales that actual impacts (e.g., on water resource systems) will be felt, and at which most water planning and management decisions will have to be made.

Currently, we have only very rough estimates of the effects of large-scale climate changes on regional and local phenomena. Impact evaluation has been particularly sparse in the areas of hydrology and water resources (Gleick, 1986; 1990). Detailed analyses are required in order to understand the ways in which water resources and water demand will be affected in specific locations.

On the supply side, it will be necessary to develop regional and local data for the future: temperatures (means, extremes, and timing);

Table 2

Sectoral Water Use in Selected Countries

Sectoral Use in Percent*

	Public Supply	Industry (Processing)	Power (Cooling)	Agriculture (Irrigation)
AFRICA				
Algeria	13	6	0	81
Sudan	2	0	0	98
Uganda	43	0	0	57
AMERICAS				
Argentina	9	8	10	73
Mexico	5	7	0	88
USA	10	11	38	41
ASIA				
India	3	1	3	93
Japan	17	33	0	50
Turkey	7	2	7	85
EUROPE				
Netherlands	5	24	40	32
UK	23	41	35	1
USSR	8	15	14	63

*May not sum to 100 percent due to rounding.

Source: WHO, 1988

precipitation (amount, type, timing, frequency, duration, intensity); wind patterns (directions, velocities, timing); runoff (amount, intensity, duration, timing); soil moisture (means, extremes, timing); and evapotranspiration (rates, means, extremes, timing). In terms of demand, water planners and managers need much better information regarding potential changes in growing seasons (length, timing), heating and cooling days (number, intensity, extremes), water costs, and population.

Some work has focused on these issues, but much remains to be done. The uncertainty tied to potential global climate changes pose very vexing problems for water managers. The stakes are extremely high since potential impacts include vastly altered patterns of temperature and precipitation, changes in the timing and location of agricultural productivity, and rising sea levels and coastal inundation. The processes of global warming will be very difficult to slow or reverse (since this would require substantial reductions both in fossil fuel burning and tropical deforestation). Adaptation to altered conditions will require planning, commitment and resources. The prospect of such changes makes water resources management all the more problematic.

Conclusion

Water may well be the most precious resource on the planet. It touches virtually all aspects of our lives. Its provision in adequate quantities and with quality matched to its intended use is an increasingly difficult task. The growth of human populations, increasing patterns of urbanization and industrialization, the introduction of synthetic materials, and many other factors are severely straining the world's water resources. However, technologies are being developed that will stretch supplies and restore quality. More importantly, perhaps, there are some hopeful signs that awareness of needed changes in our behavior and use of water is increasing worldwide. Only when we come to realize that water, while abundant in absolute terms, can be extremely scarce at particular times and places, will we begin to utilize it with the care it requires.

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A Learning Activity to Accompany
Water in the Global Environment

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Introduction:

These learning activities are based upon the essay *Water in the Global Environment.* Using a variety of approaches the students will gain a better understanding of water in Earth's environment and society.

Grade Level: Grades 7-9

Time Required: Two weeks (if all activities are used)

Themes/Key Ideas: Relationships within Places: Human and Environment Interaction

Objectives: At the end of this unit students will be able to:

Knowledge:

Understand the complexity of water issues.

Understand the basic concept of the hydrologic cycle.

Understand some of the jobs associated with water.

Understand that our environment is very fragile.

Skills:

Analyze information in pie graphs.

Use maps and other resources to develop conclusions.

Attitudes/Values:

Appreciate the importance of water in today's environment.

Materials Needed:

World Almanac, Essay "Water in the Global Environment", Dictionary, Encyclopedia.

National Geographic Society. 1989. *Exploring Your World: The Adventure of Geography.* Washington, D.C.

The Learning Activities

Day 1: Pre-test (Handout 1): Have the students answer as many questions as they can without any outside help. Later allow the students to use the essay *Water in The Global Environment* to finish their pre-test. Review to make sure the students have the correct answers.

Day 2: Since several concepts or words from the pre-test are difficult have the students work on the vocabulary words (Handout 2). Most of these words are explained in the article; otherwise, use a dictionary, earth science textbook or an encyclopedia to define these words.

Day 3: Arrange for a guest speaker from the suggested guest speaker list (Teacher Resource 1, page 39).

Day 4: Have the students do research from the suggested research topics list (Teacher Resource 1).

Day 5: Have the students examine flood plain maps (Teacher Resource 1, Map Work). Show slides of the results of floods, droughts, dams, reservoirs, etc... (Teacher Resource 1, Slides to Show in the Classroom). Lead a class discussion based on students' observations and conclusions related to the maps and slides used.

Day 6: Have the students debate one of the suggested topics (Teacher Resource 1, Debate Topics).

Day 7: Have the students complete the Hydrologic Cycle worksheet (Handout 3) and answer the Pie Graph questions (Handouts 4 and 5).

Day 8: Use the World Almanac to answer the questions about major flood disasters (Handout 6); then choose a topic for research (Handout 7).

Day 9: Look at Table 2 (page 21) in the essay *Water In The Global Environment* to answer questions on Sectoral Water Use (Handout 8). Lead a class discussion about the differences between developed and developing nations.

Day 10: Use the Water Facts handout to complete the crossword puzzle (Handouts 9 and 10).

HANDOUT 1:

Pre-test On Water

1. Is there a fixed amount of water on our planet?

2. What are the three states (forms) of water?
   A.
   B.
   C.

3. What is the process by which water is cycled through the Earth's environment?

4. List types of areas where evaporation takes place?

5. The process of evaporation from leaves of plants is called ______________________.

6. The molecular make up of water is?

7. List four purposes for dams?
   A.
   B.
   C.
   D.

8. Where was the first-known dam built over 5,000 years ago?

9. Name at least three purposes for the creation of storage reservoirs.
   A.
   B.
   C.

10. Name up to six negative impacts of reservoirs.
    A.
    B.
    C.
    D.
    E.
    F.

11. In order for rain drops to form and fall, what two conditions are necessary?
    A.
    B.

12. List three qualities of water.
    A.
    B.
    C.

13. List two environmental extremes that affect water supply.
    A.
    B.

14. List six properties of water.
    A.
    B.
    C:
    D.
    E.
    F.

15. If global warming continues what is the main concern?

16. If global warming continues what aspects of our climate may change?
    A.
    B.
    C.
    D.

HANDOUT 2:

Water Vocabulary and More

1. surface water—

2. recharge—

3. aquifer—

4. transpiration—

5. evaporation—

6. condensation—

7. water diversion—

9. storage reservoirs—

10. groundwater—

11. weather modification—

12. condensation nuclei—

13. desalination—

14. brackish—

15. watershed—

16. infiltration—

17. percolation—

18. terracing—

19. contour plowing—

20. flood—

21. drought—

22. monsoon—

23. famine—

24. levees—

25. seawalls—

26. eutrophication—

27. pathogens—

28. highly industrialized nations—

29. newly industrializing nations—

30. low-development countries—

HANDOUT 3:

1, 2, 3
The Sequence of the Hydrologic Cycle.

Put the following components of the hydrologic cycle in correct sequence by putting them in order by number.

______ Clouds are formed.

______ Water vapor rises.

______ Water droplets grow in size and become heavy.

______ Water evaporates.

______ Water becomes soil moisture or groundwater, is evapotranspirated to the atmosphere, or is stored as ice or in lakes and reservoirs.

______ Solar radiation heats up water particles.

______ Water vapor condenses on dust and other atmospheric particles and forms droplets.

______ Water returns to the ocean as runoff.

______ Water vapor cools.

______ As water evaporates it changes to a gaseous state (water vapor).

______ Water drops become heavy enough to fall to the earth.

HANDOUT 4:

Using Pie Graphs

Looking at Pie Graph #1:

1. What percentage of all the earth's water is in the ocean?

2. That leaves _________ percent for fresh water lakes, salt water lakes, atmosphere, icecaps and soil moisture.

Looking at Pie Graph #2:

3. Of the 2.5 percent water that is not in the ocean as salt water, what accounts for most of the remaining 2.5 percent?

4. This leaves _________ percent for the world to use for irrigation, drinking water, domestic uses, industry and electrical energy production.

Looking at Pie Graph #3:

5. How much fresh water is in the atmosphere?

6. The majority of the fresh water represented in Pie Graph #3 is in the _________.

Thought Questions:

7. Why do you think there is so much moisture in the soil?

8. What is happening to some of the water in the atmosphere?

9. Is it necessary to protect the amount of fresh water we have? Why?

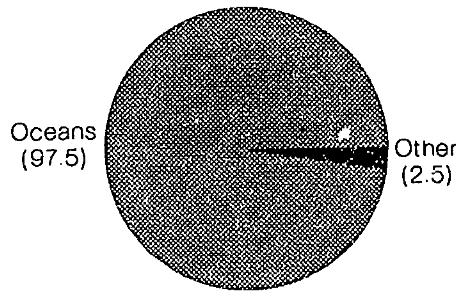
10. What are some alternatives for our drinking water supply?

11. What are some positives to your suggestions?

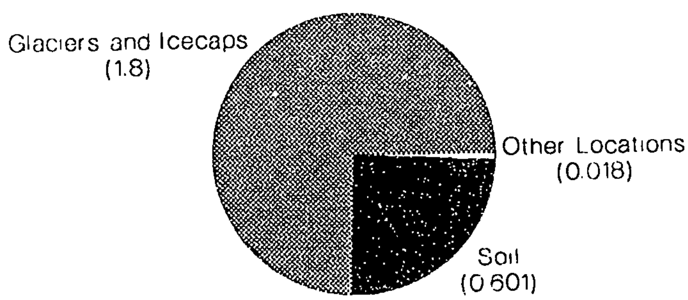
12. What are some negatives to your suggestions?

HANDOUT 5:

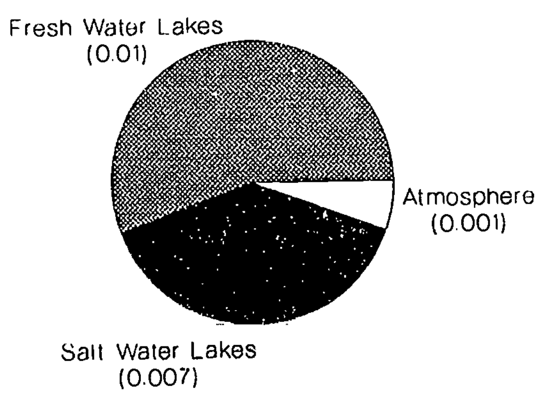
Pie Graph #1
Distribution of Global Water (%*)



Pie Graph #2
Distribution of Non-Ocean Water (%*)



Pie Graph #3
Other Locations in Detail (%*)



*[*Percentages reflect portion of total global water supply.]*

HANDOUT 6:

Major Disastrous Floods from 1900-1989

(Use the *World Almanac* to answer the following. Note only the floods that have caused over 1,000 deaths.)

1. Since 1900 there have been 24 major floods and tidal waves. How many of these have affected highly industrialized nations (also called first world countries)?

2. List these highly industrialized nations or areas that were affected and the year that the flood occurred.

3. All of the other severe floods and/or tidal waves occurred in _______ developed nations.
   A. highly
   B. newly
   C. less

4. The most deaths overall occurred in what country?

5. List all the possible reasons why you think this country has had so many disastrous floods.

6. How many deaths have occurred due to major floods in China; India; Bangladesh?

HANDOUT 7:

Research

1. Choose any of the major floods that occurred between 1889-1989. Find out the major cause of the flood and how lives could have been saved. Come up with a scenario and a solution for the event. How could you have made a difference if you had the ability to go back in time to one of these areas before the flood occurred. Remember the time travel law: you can not just go back and tell them what is going to happen.

2. Did greed cause the death of 2,200 people in the Johnstown Flood in 1889?

3. What is the Clean Water Act of 1972?

HANDOUT 8:

Looking at Sectoral Water Use

1. Which country has the highest percentage of public water supply usage?

2. Why do you think India's public water supply is so low? (In other words, where do people in India get their drinking water?)

3. Look at the countries with 57 percent or higher usage for agriculture. Are these countries developing or developed?

4. The only country that uses more water for cooling in electric power production than the U.S.A. is ______________________ ?

5. What sectoral usage titles help you to determine if a country is developing or developed?

6. Which developed country uses the least amount of water for agricultural irrigation?

7. Which country has water usage most evenly distributed among sectors?

8. Which continent seems to be the least developed, based on the sectoral water usage chart?

9. Which continent seems to be the most developed, based on the sectoral water usage chart?

HANDOUT 9:

Water Facts

1. Humans beings are 65-70 percent water.

2. Most of the plants we use for food are between 86-90 percent water.

3. Without water this planet's temperature would fluctuate so much that the earth would be largely uninhabitable.

4. Water is the the only natural resource which exists in all three states (forms) -- gas, liquid and solid -- and therefore is easily stored and transported around the planet.

5. Water is unevenly distributed on the earth.

6. Given enough time water can dissolve almost any substance.

7. Water molecules can easily "squeeze in" between molecules of other materials.

8. Some of the earliest human engineering works were aimed at providing water.

9. Ninety-seven percent of the earth's water is in the oceans.

10. According to the World Health Organization (WHO), 60 percent of the world's rural population does not have access to reliable, safe water supplies.

11. WHO estimates that 25 percent of the world's urban population does not have access to reliable safe water supplies.

12. WHO estimates that 84 percent of rural residents in the world lack adequate sewage disposal.

13. WHO estimates that 41 percent of urban residents in the world lack adequate sewage disposal.

14. An average of 25,000 people die each day as a result of waterborne diseases.

15. On a global scale, 80 percent of all water withdrawals are for agricultural purposes.

HANDOUT 10:

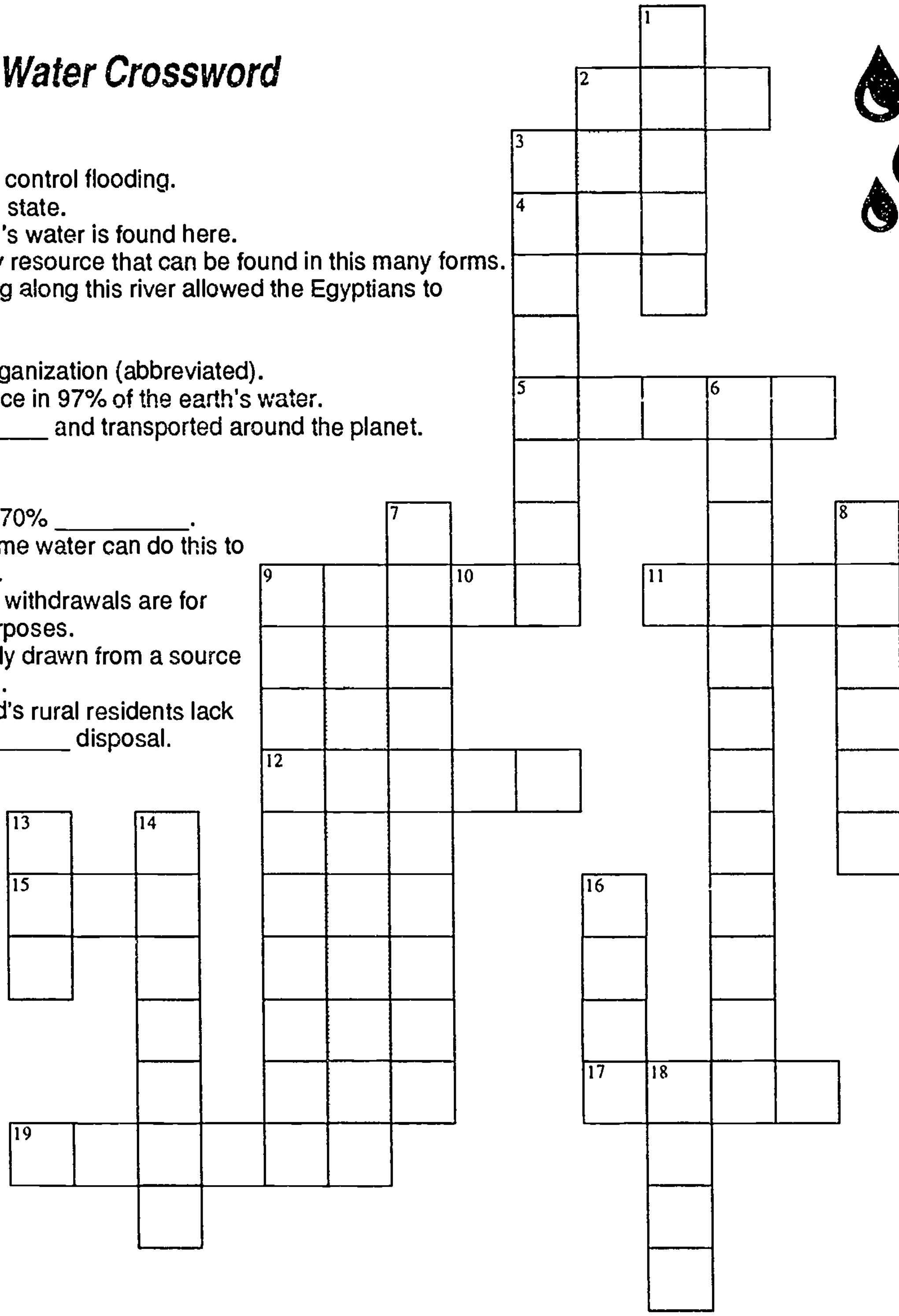
Water Crossword

ACROSS

2. Structure built to control flooding.
4. Water in its solid state.
5. 97% of the earth's water is found here.
9. Water is the only resource that can be found in this many forms.
11. Early engineering along this river allowed the Egyptians to control flooding.
12. Opposite of day.
15. World Health Organization (abbreviated).
17. A major substance in 97% of the earth's water.
19. Water is __________ and transported around the planet.

DOWN

1. Humans are 65-70% __________.
3. Given enough time water can do this to almost anything.
6. 80% of all water withdrawals are for __________ purposes.
7. Water specifically drawn from a source for use on crops.
8. 84% of the world's rural residents lack adequate __________ disposal.



9. An average of _____ thousand die each day due to waterborne diseases.
13. Number of hydrogen atoms in each water molecule.
14. The main purpose of most dams on rivers is for flood __________.
16. Red, Yellow, Black, White are all __________.
18. A sea located in Commonwealth of Independent Republics.

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TEACHER RESOURCE 1:

Ideas to Enhance the Importance of Water

Research topics:

1. Traditional Rainmakers versus Modern Rainmakers
2. Drought and its effect on an area / region / continent
3. Monsoons and their effect on an area / region / continent

Map Work:

1. Flood plain maps of your area or other nearby cities with which the students are familiar can be obtained from local real estate agencies or the city planning office.
   - A. Using these maps have the students locate dangerous flood plain areas where they would not want to buy a house.
   - B. Direct the students to consider why the more affluent areas of large cities are often located away from rivers.

Suggested Guest Speakers:

A representative of:

1. State Water Commission or Department of Environmental Affairs.
2. State Agriculture Department.
3. Area Sewage Treatment Plant.
4. City water officials or local water supply company.
5. Local Water Development Projects or Tennessee Valley Authority.

Slides to Show in the Classroom:

1. Slides of area dams or slides of famous dams such as Hoover dam, Espada dam (the oldest dam in North America located in San Antonio, Texas).
2. Lakes formed by dams.
3. Seawalls.
4. The results of droughts, rainy monsoon season, floods.
5. Canyons formed by running water.
6. LANDSAT images of rivers and their floodplains. (These can be obtained from city planning offices or agencies such as NASA.)

If slides are not available, photographs can be used.

TEACHER RESOURCE 1 (cont'd.)

Debate Topics:

1. *Who owns the water?*
   A. One side can represent the community. In this community are several farmers who depend on irrigation.
   B. The other side can represent the owners of land who are pumping out all the water they can and selling it to a city several hundred miles away. This action is using up a large portion of this community's water supply.

2. ***To increase the efficiency and conservation of water the city council has proposed a sharp increase in the price of water to discourage overuse.***
   A. One side represents low income families who can not afford to pay increased water prices, as well as local industry that uses a lot of water to produce products.
   B. The other side represents environmentalists and scientists who have predicted a severe water shortage in the future at the rate the town is currently using water.

3. ***City officials versus the farmers.***
   A. Your town is poor, with approximately 35,000 people.
   B. Your town has one industry that hires over 2,000 employees.
   C. This industry, a food packaging plant, uses thousands of gallons of water daily.
   D. A small number of people in the town are involved in harvesting crops or are farmers.
   E. A river flows through the town; most farms are located along this river.
   F. You have had a water shortage in the summer the last four years, with each year getting worse as the population, industry, crop production have grown.

   There is a proposal to build a reservoir to help alleviate the water shortage. In order to create a reservoir, a dam must be built on the river.
   A. One side is the citizens who realize that this reservoir will require a tax increase; and that the building of this dam will result in some of the farmers losing land that has been in their families for generations.
   B. The other side is the city officials who are responsible for the whole town's welfare. They realize that they are headed for disaster if water supply is not increased (You may want to explore options other than the building of a reservoir.)

   (For real life situations write to Alamosa Chamber of Commerce, Cole Park, Alamosa, CO 81101.)

TEACHER RESOURCE 2:

Answer Keys

Pre-Test On Water

1. Yes, there is a fixed amount.
2. A. Liquid
   B. Gas -water vapor
   C. Solid -ice
3. Hydrologic Cycle
4. Lakes, streams, rivers, oceans, soil
5. Transpiration
6. H_2O
7. A. Water supply
   B. Hydropower production
   C. Flood control
   D. Recreation
8. Egypt
9. A. Long range planning
   B. More flexibility for societies
   C. Lower dependence on nature
10. A. Loss of land for native plants, animals and people.
    B. Reduction of silt downstream leading to changes in erosion.
    C. Changes in streamflow and flooding characteristics.
    D. Increased evaporation which might rob areas downwind of precipitation.
    E. Alteration of recharge rates to groundwater aquifers.
    F. Alteration of climate of region.
11. A. Adequate supply of moist air.
    B. Presence of particles such as dust, salt or other materials onto which water molecules can adhere and form drops large enough to fall to earth.
12. A. Odorless
    B. Tasteless
    C. Colorless
13. A. Flooding
    B. Drought
14. A. Turbidity
    B. Color
    C. Temperature
    D. Presence of gases and solids
    F. Biological organisms
15. A. Precipitation
    B. Evapotranspiration
    C. Circulation and wind patterns
    D. Cloud development

The sequencing of the hydrologic cycle

_7_ Clouds are formed.
_4_ Water vapor rises.
_8_ Water droplets grow in size and become drops.
_2_ Water evaporates.
_10_ Water becomes soil moisture or groundwater, is evapotranspirated to the atmosphere, or is stored as ice or in lakes and reservoirs.
_1_ Solar radiation heats up water particles.
_6_ Water vapor condenses on dust and other atmospheric particles and forms droplets.
_11_ Water returns to the ocean as runoff.
_5_ Water vapor cools.
_3_ As water evaporates it changes to a gaseous state (water vapor).
_9_ Water drops become heavy enough to fall to the earth.

Using the Pie Graphs

Looking at Pie Graph #1:

1. 97.5 percent
2. 2.5 percent

Looking at Pie Graph #2:

3. Glaciers and Icecaps
4. .618 percent

Looking at Pie Graph #3:

5. .001 percent
6. soil

Thought Questions:

7. Water percolates into the soil and perhaps works its way into groundwater.
8. Acid precipitation pollution.
9. Yes; answers will vary.
10. Answers may vary, but should include desalinization.
11. An abundance of ocean water.
12. Cost and the difficulty of transportation between the ocean and places far from the ocean.

Looking at Table 2 on Sectoral Water Use

1. Uganda
2. Rivers, wells, lakes
3. Developing
4. Netherlands
5. Industry and power
6. U.K.
7. U.S.A.
8. Africa
9. Europe

A Learning Activity to Accompany Water In The Global Environment

Linda Beckam
Tulsa Public Schools
Tulsa, Oklahoma

Introduction:

Seventy-one percent of the earth's surface is water, but it is misleading to believe that the supply of fresh water is almost unlimited. In fact, less than 1 percent of the earth's water is actually suitable for human consumption. In this activity students will consider the many ways in which a community uses water and identify possible solutions for water shortages.

Grade Level: Grades 8-10

Time Required: 2-3 class periods

Themes/Key Ideas: Relationships Within Places: Human and Environment Interaction

...Relationships within places include how people interact with the environment.

...Relationships within places include how people adapt to or modify the environment.

Special Vocabulary/Concepts: drought; water shortage

Objectives: Upon completion of this activity, students will:

Knowledge: Understand the many ways a community uses water.
Understand that in some communities water is in short supply.
Be aware of the effects drought and water shortages have on communities.

Skills: Classify community water uses as essential or non-essential.
Analyze a water use problem.
Evaluate various solutions to a water use problem.

Attitudes/Values: Form and defend an opinion about a water use problem.

Materials: Dilemma card (Handout A), one for each student

**The original concept for this learning activity was developed during the Special Publications Writers' Workshop at the 1991 NCGE Annual Meeting in St. Paul, Minnesota. Ideas were also contributed by William E. Amburn of Bartlesville, Oklahoma, and Jim Lennert of Naperville, Illinois. The activity was edited by workshop leaders Celeste Fraser and Martha Sharma.*

The Learning Activity

Background: Refer to the essay *Water in the Global Environment* in this publication.

Introducing the Activity:

To guide students to consider ways their community uses water, ask them first to think about their personal use of water. In what ways do they use water each day? How much water do they use? Are they always careful about the ways they use water? Discuss the meaning of essential (important to the extent that one cannot do without it) versus nonessential (possible to do without it) uses of water. Encourage students to consider their own use of water in terms of essential and nonessential uses.

Developing the Activity:

1. Continue by asking students to identify ways their community uses water. Make a list on the chalkboard or on sheets of newsprint as students respond. Also identify different groups in the community who use water.

2. Divide the class into groups of three or four students, each group representing a different community group. Ask the groups to classify the examples of water use as essential or nonessential to the community. Compare the classifications of the various groups and discuss the similarities and differences.

3. Ask students what types of changes could have an impact on water use in the community. On the chalkboard write the words "drought" and "water shortage." As a class, discuss the difference between these terms. [Be sure that students understand that a drought is a prolonged period with below normal precipitation; and that a water shortage is an insufficient supply of water due to a drought or to a change in human demand for or use of available water. In other words, a drought may result in a water shortage, but not every water shortage is the result of a drought.]

4. Distribute copies of the Dilemma Card (Handout A) to each student. Still working in small groups, have students read the dilemma and restate the problem in their own words. Be prepared to help students clarify the circumstances of the problem if necessary.

5. Direct each group to evaluate the dilemma and propose the best solution to the problem. Have each group present and defend its solution to the class. Encourage discussion of the strengths and weaknesses of each proposed solution. Determine which ideas are practical or impractical as possible solutions.

Concluding the activity:

Discuss with students similar dilemmas that have or could occur in their own community. Brainstorm possible solutions.

Alternative Strategies

Have students evaluate the dilemma from the perspective of a particular interest group, e.g., community activists, environmentalists, a labor union from Acme Chemical Company, farmers, owners of Acme Chemical Company, etc.

Consider the dilemma from the perspective of different climate regions.

Encourage students to devise a personal action plan to prevent a similar dilemma from happening in their community.

HANDOUT A:

The Town of Ridgewell vs. Acme Chemical Company

Ridgewell is a town of 30,000 located in the midwestern United States. The town has a diversified economy based on commercial farming, industry, and service activities. In most years precipitation is sufficient to meet the town's needs, but the area has a history of periodic drought.

Acme Chemical Company has been a major employer within the community for the past 18 years. The Company's management has always been civic minded and supportive of the community's many projects. However, the drought that has plagued the area over the past year and a half has created serious tension between Acme Chemical Company and the town.

The Ridgewell City Council has mandated a one-third reduction in water usage for all business and individual users. Acme uses water both as a coolant and in the production of the various chemical products that it manufactures. If forced to reduce its water usage, Acme will have to cut back production. Many of the townspeople are employed by Acme Chemical Company, and a reduction in production will mean layoffs for many workers.

If Acme Chemical Company does not reduce its water usage, the private use of water will have to be reduced by as much as one-half. The townspeople do not want to reduce their use of water by that much and insist that everyone -- businesses and individuals alike -- should share in the problem.

Rumor has it that Acme's owners are considering moving the company to another area if Ridgewell cannot guarantee the company an adequate supply of water.

Dilemma:

How can this dilemma be solved? Whose needs are greater -- business or individuals? What would be the consequence of layoffs or moving the company? What other interest groups might become involved?

Learning Activities to Accompany Water In The Global Environment

Martha Bock, Ph.D.
Montgomery College
Rockville, Maryland

Introduction:

This lesson will focus on water in the global environment. Several methods are suggested including readings, map exercises, vocabulary exercises, discussions, and a guest panel discussion. Skill development includes asking geographic questions and presenting geographic information.

Grade Level: Senior High School/ College

Time Required: Five Class Periods

Themes/Key Ideas: Location, Place, Relationships Within Place: Humans and Environments

Concepts: Accessibility, Agriculture, Cultural Ecology, Hydrologic Cycle, Ecosystem, Greenhouse Effect, Pollution

Objectives: At the completion of this unit, students will be able to:

Knowledge:

1. Identify several critical water issues.
2. Determine the severity of water issues.
3. Analyze competing demands for available water resources.
4. Analyze how decisions about water policy are made.
5. Understand how water issues are resolved.
6. Analyze personal and global impacts of water issues.

Skills:

1. Present issues to students and ask them to develop geographic questions.
2. Interview; identify appropriate people to interview.
3. Translate tabular and graphic information to verbal form; describe trends.
4. Exercise deductive reasoning (identify relevant questions; collect and assess appropriate evidence).
5. Read maps.
6. Use atlases to gather data.

Attitudes/Values:

1. Understand the fragility of the environment.
2. Understand the destruction of irreplaceable resources.
3. Appreciate different points of view.
4. Appreciate the value of teamwork.
5. Appreciate the interconnectedness of water issues.

Materials:

Newspaper, magazine, or journal articles on water issues, transparencies, marking pens, overhead projector, outline world maps, copies of Table 2, VHS tape on global water issues, table and chairs for panel discussion, atlases

Suggested Materials:

VHS Tapes:

Acid Rain: New Bad News. Nova: Ambrose Video Publishing, Inc. 1987. 381 Park Ave. South, New York, New York 10016. 1-800-526-4663. Length: 25 minutes.

"The Ocean Planet: The Death of the Mississippi", in *The Blue Revolution Series*. Films for the Humanities and Sciences, P.O. Box 2053, Princeton, New Jersey 08543-2053. 1-800-257-5126. Length: 23 minutes.

"Water and Life: A Delicate Balance", in *The Blue Revolution Series*. Films for the Humanities and Sciences, P.O. Box 2053, Princeton, New Jersey 08543-2053. 1-800-257-5126. Length: 13 minutes.

The Effects of Water Pollution, Films for the Humanities and Sciences, P.O. Box 2053, Princeton, New Jersey 08543-2053. 1-800-257-5126. Length: 19 minutes.

The Great Lakes Region: Industries, in *The Great Lakes Series*. Hawkhill Associates, Madison, Wisconsin. Length: 15 minutes.

Articles:

Toufexis, Anastasis. The Dirty Seas, *Time*, Vol. 132, No. 5. August 1, 1988, pp. 44-50.

Maurits la Riviere, J. W. Threats to the World's Water, *Scientific American*, Vol. 261, No, 3. September 1989, pp. 80-94.

Is There a Federal Commitment to a National Water Policy? *U. S. Water News*, June 1987, p. 7. (*U.S. Water News*, 230 Main Street, Halstead, Kansas 67056. There are numerous appropriate articles available in this paper.)

Other Resources:

Water Education Bibliography/Directory: An Annotated Bibliography of Current Resources for Water Education. Water and Man, Inc., Bountiful, Utah 84010. (This is an invaluable resource.)

The Learning Activities

ACTIVITY ONE:

1. To introduce this lesson on water in the global environment, distribute newspaper or magazine articles discussing water quality issue (see resource list). Alternatively, the articles can be distributed during the class prior to the beginning of the unit. The students can record their ideas and observations in their journals and the lesson can begin with a discussion of the assignment.

2. Ask the students to respond in their journals to the content of the articles. Allow ten minutes for the completion of this exercise. (Having students keep a journal is an excellent method for encouraging students to record their ideas and observations).

3. At the end of ten minutes, ask the students to stop writing and to share their responses with the rest of the class.

4. To prompt the sharing process, ask questions concerning the content of the articles. For example, ask students to determine if water quality affects them personally, and if so, how? Also, ask students if water is a renewable resource. As students respond, note the answers on the chalkboard.

5. Review the students' responses. Ask the students the following question. How does our planet get its water resources?

6. Distribute copies of the hydrologic cycle or use an overhead transparency of the hydrologic cycle (see page 4). Discuss the hydrologic cycle and ask for comments or questions.

7. After all students who wish have asked questions or made comments, break the class into small groups of three or four students each. Have the students arrange their desks so that they are facing each other. Insist on the arrangement of the desks so that each student within the group will be able to listen to other members of the group and will be able to participate effectively.

7. Instruct the groups that their task is to search for underlying causes and effects in water issues. The second task of the groups is to suggest solutions for any negative effects they discover.

8. Give each group a transparency and a marker. Have the group select one person to write and one person to present the group findings to the class. Allow 15 to 20 minutes for completion of the group process.

9. After twenty minutes, ask the students to return to a large group setting.

10. Have the student selected as speaker report the group findings to the rest of the class via transparency and overhead projector. Limit the presentations to three to five minutes; however, encourage the class to ask questions and take notes.

11. After all the groups have presented their findings, note the similar responses and any unique solutions.

12. Available water supply for demand, water as a nonrenewable resource, and pollution will probably be three areas on which students concentrate their responses.

13. List any probable solutions to water problems not mentioned on the chalk board. Suggested responses include:
    a. new water development
    b. weather modification
    c. desalinization
    d. watershed management
    e. interbasin transfers
    f. use of evaporation suppressants
    g. towing of icebergs
    h. conservation

14. Conclude the lesson with a brief discussion of the feasibility of each of these methods. Note that each of these solutions is becoming increasingly expensive; thus, the methods which emphasize managing demands, increasing water use efficiency, and reusing supplies will become increasingly important.

15. Assignment: Distribute a list of the properties of water quality (see pp. 14-17 in the essay). Instruct the students to define each term and to note its relationship to water quality. They should record their responses in their journals. Instruct the students to watch the local and/or national news or check a newspaper to determine some water issues that are of local, national or international concern. Have the students note their findings in their journals.

ACTIVITY TWO:

1. To begin the lesson, ask several students to summarize the lesson from the previous day. Then, ask the students to detail local, state or national water issues they discovered watching the news or from the newspapers. Direct all students to refer to their journals and class notes, and allow time to discuss any points needing clarification.

2. Ask the students to look at their list of definitions of the properties of water quality. Have prepared a transparency with the definitions. Place the transparency on the overhead projector and discuss the definitions. Allow time for questions or comments.

3. After completing discussion of the definitions of the properties of water quality, distribute three world maps. Have students mark/shade one map indicating the highly industrialized nations, one map indicating the newly industrializing nations, and one map indicating the low-development countries. (Refer to an atlas, if necessary.) Ask what water issues have arisen in each of the regions because of industrialization.

4. Distribute copies of Table Two (see essay, p. 21). Instruct the students to study the table and pose questions and answers about the economic base of each of the countries listed. Have the students record their responses in their journals. Allow students ten minutes to complete their analyses.

5. Based on their findings, ask the students what kinds of water pollution problems each of these areas is most likely to experience and why. Note the responses on the chalk board under a three-columned chart.

6. At the conclusion of this activity, point out the time compression factor in rapidly developing nations if the students have not considered this aspect of the problem.

7. End the day's lesson with the tape, *Acid Rain: New Bad News*, or one of the other tapes on the suggested list. Have the students take notes highlighting the salient points of the tape's content.

8. Assignment: Using the notes taken during the tape, have the students write a short paper (200 words) summarizing the major points of the tape. Ask students to consider in their papers whether water pollution is a major cause for concern.

EXTENSION ACTIVITY:

1. Begin the lesson with a discussion of the papers the students completed the previous day. Note the major water problems students mention on the chalkboard. Arrange the responses in chart fashion under the following topics.

   Global warming
   Competition for available water supplies
   Waste management
   Pollution
   Conservation
   Acid Rain

2. Depending on the size of the class, break the class into small groups of three to four students each. Assign each group one of the topics listed on the chalkboard.

4. Have students move to their assigned groups. Explain that the task of the group is to research the assigned topic and, based on their findings, select a person from the community who can represent their topic in a panel discussion. The date for the panel discussion can be set and written on the board before the groups move to their assigned locations.

5. Each group must contact the person who will serve as guest speaker, explain the topic which the speaker is to address, and prepare a follow-up letter to confirm the speaker's participation.

6. Each group must prepare a list of pertinent questions to distribute to the class for briefing prior to the panel's discussion.

7. On the day of the panel discussion, a member of each group must introduce the speaker the group selected and give a brief overview of the speaker's position and background.

8. Before the day for the panel discussion, the group should have sent the guest panelist a confirmation letter and a copy of the questions distributed to the class. As an alternative, the panel discussion can be held in the evening to allow ample time for each panelists to present his/her information and to allow for community involvement.

9. On the day of the panel discussion, have the designated group member introduce the appropriate panel member and proceed with the panel discussion.

10. After the panel discussion is completed have each group's selected person thank the members of the panel. The group also is responsible for a follow-up thank you letter.

11. If possible, a reception can follow the panel discussion.

EVALUATION:

1. On the day following the panel discussion, have the groups meet to complete thank you letters. At the same time, have the groups complete a report. Have the students include who was responsible for which task, how effectively the task was accomplished, and how effective the panel discussion was overall.

2. As a final evaluation activity, a group report detailing the views of the panel and conclusions reached as a result of the panel discussion can be submitted. Alternatively, each student can write and submit a paper of approximately 300 to 500 words discussing water issues. Have the students use their journal entries, classnotes, research done to prepare for the selection of the guest panelists, and information presented by the panelists as the basis for the papers.

3. In evaluating for a grade, both a group grade and an individual grade can be assigned.

Selected Resource List*

The purpose of this publication is to provide educators with an introduction to some of the important issues related to water in the global environment and with learning activities that facilitate presentation of these issues in the classroom. It is not within the scope of this book to address all issues related to water. Educators are encouraged to use this book as a springboard for their own research.

Many sources of information related to water and water issues are available. A school or public librarian can assist in identifying book and periodical sources that are available locally. A good source of maps and other data related to water is:

Van der Leeden, Frits, Fred Troise, and David K. Todd. *The Water Encyclopedia.* Chelsea, Michigan: Lewis Publishers, 1991.

In addition, the following resource list is provided to help educators begin their own investigation of topics in which they or their students have a particular interest.

Federal Agencies

Environmental Protection Agency (EPA)
401 M Street, SW
Washington, DC 20460

. . . *Drinking Water*
Michael B. Cook, Director
(202) 382-5508
(800) 426-4791

. . . *Municipal Pollution Control*
Michael J. Quigley, Director
(202) 382-5850

. . . *National Drinking Water Advisory Council*
Charlene Shaw, Contact
(202) 382-2285

. . . *Water Regulations and Standards*
Martha G. Pronthro, Director
(202) 382-5400

* Compiled and edited by John E. Benhart, Department of Geography and Earth Science, Shippensburg University of Pennsylvania, and Martha B. Sharma, Vice President, Publications & Products, National Council for Geographic Education.

Nongovernmental Agencies

Clean Water Action
1320 18th St., NW
Washington, DC 20036
David R. Zwick, Director
(202) 457-1286

Friends of the Earth
218 D St., SE
Washington, DC 20003
Michael S. Clark, Executive Director
(202) 544-2600

Izaak Walton League of America
1401 Wilson Boulevard
Arlington, VA 22209
Jack Lorenz, Executive Director
(703) 528-1818

National Association of Conservation Districts
509 Capitol Court, NE
Washington, DC 20002
Ernest C. Shea, Executive Vice President
(202) 547-6223

National Audobon Society
801 Pennsylvania Ave., SE
Washington, DC 20003
Elizabeth Raisbeck, Senior Vice President, Governmental Affairs
(202) 547-9009

National Resources Defense Council
1350 New York Ave., NW
Washington, DC
Donna M. Wilcox, Office Manager
(202) 783-7800

National Water Alliance
1225 Eye St., NW
Washington, DC 20005
Rep. Henry J. Nowak, D-NY, Chairman
Ron Linton, President
(202) 646-0917

National Wildlife Federation
1400 16th St., NW
Washington, DC 20036
Jay D. Hair, President
(202) 797-6800

Resources for the Future
1616 P St., NW
Washington, DC 20036
Robert W. Fri, President
(202) 328-5000
Information
(202) 328-5009

United States Chamber of Commerce
Food, Agriculture, Energy, and Natural Resources Policy
1615 H St., NW
Washington, DC 20062
Stuart Hardy, Manager
(202) 463-5533

Water Pollution Control Federation
601 Wythe St.
Alexandria, VA 22314
Quincalee Brown, Executive Director
(703) 684-2400

World Resources Institute
1709 New York Ave., NW
Washington, DC 20006
(202) 638-6300

State Agencies

Most states have agencies charged with supervision and maintenance of water standards at the state and local levels. The following list, reflecting such agencies for the state of Pennsylvania, is provided as a model for indentifying similar agencies in other states.

Department of Environmental Resources (DER)
Harrisburg, PA
. . . *Bureau of Dams and Waterway Management*
. . . *Bureau of Forestry*
. . . *Bureau of Soil and Water Conservation*
. . . *Bureau of Topographic and Geologic Survey*
. . . *Bureau of Water Projects*
. . . *Bureau of Water Quality Management*
. . . *Bureau of Water Resources Management*
. . . *Environmental Quality Board*
. . . *Resources Management*
. . . *Wetland Information*

Dauphin County Emergency Management Agency
Harrisburg, PA

Department of Education
Academic Programs

Environmental Protection
Harrisburg Regional Office
. . . *Home Water Testing Kits*
. . . *Water Quality*

Fish Commission
Harrisburg, PA
. . . Executive Office
. . . Bureau of Education and Information

Joint Legislative Air and Water Pollution Control and Conservation Committee
Harrisburg, PA

City of Harrisburg, PA
. . . Public Works-Water Office
. . . DeHart Dam Advanced Waste Water Treatment Plant

Harrisburg Water and Sewer Authority

Soil Conservation Service
Harrisburg, PA

State Library
Harrisburg, PA
. . . School Library and Media Educational Resources Services

About the Authors

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Martha Bock

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Marvin Waterstone

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