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GLEN C. SANDERSON

ILLINOIS RESOURCE MANAGEMENT

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TEACHING WATER CONSERVATION

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ILLINOIS RESOURCE MANAGEMENT

WATER CONSERVATION TEACHER'S MANUAL

by

J. LOREENA IVENS
Technical Editor

Illinois State Water Survey
Urbana, Illinois

CONTENTS

FOREWORD

Water forms a major part of the boundary of Illinois. In addition to boundary waters there are many rivers, lakes, and smaller ponds that are of vast economic, recreational, and aesthetic value to the State.

Pollution has an alarming effect upon the lives of people, wildlife, and vegetation. The amount of water probably is as great as it ever was, but distribution of usable water has become a major problem in this age of population increase, industrial expansion, air conditioning, and the interest in recreational areas.

This manual has been produced by personnel of the Illinois State Water Survey to provide information related to the use and management of water in improving the ecologic environment in which we live. It should be of value to teachers and students.

Michael J. Bakalis
Superintendent of Public Instruction

ILLINOIS WATER CONSERVATION TEACHER'S MANUAL

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J. Loreena Ivens
Technical Editor
Illinois State Water Survey

INTRODUCTION: WATER CONSERVATION TODAY

Water, which is essential to all living things, is generally abundant in Illinois, but its distribution in time, place, and quality varies widely.

To assure that adequate, clean, and safe water is available to all of the people of Illinois, when and where it is needed, will require wise use and management of our total water resource.

This is water conservation—to manage wisely what we have to insure its fullest beneficial use today and in the future.

When the explorers and early settlers reached Illinois, they found a land rich in natural resources—waters, soils, forests and prairies, minerals, and fish and wildlife. These resources were used to build a large and highly productive agricultural and economic system. An abundance of water for transportation, agriculture, and industry was an important part of that growth. Today more than ten and a half million Illinois residents enjoy the benefits of this system, which still depends largely on natural resources for its wealth and strength.

The time is gone, however, when each family or community can live by a stream or dig a private well to satisfy individual water demands. Much more water is needed for many more uses, and the needs of one group may overlap those of another. Wise planning for the development, use, and management of the water resources of Illinois is essential to the progress of our growing population, as well as to the efficient use of other natural resources.

The Conservation Movement

Like others who have had an abundance of natural resources, we have been slow in realizing the need for conservation. Even as recently as 60 years ago, many people throughout the United States still seemed to think that our natural resources had no end. The effects of such thinking are evident today—tons of topsoil have been blown or washed away, many species of wildlife and plants and acres of woodlands have disappeared, and the water in most of our streams is heavily polluted.

The conservation movement to check such wastes began about the turn of the century. It was led by Theodore Roosevelt and Gifford Pinchot. Since then, through research and the application of scientific knowledge, we have learned much about preserving the resources we now have, restoring those which are renewable, finding new sources of some materials, and finding substitutes for resources which are not renewable. Millions of dollars now are being spent each year by federal, state, and local governments, and by numerous volunteer groups, for programs to study and conserve our precious natural resources. However, we are just beginning—both to learn what to do and to apply what we have learned.

Too, we face ever-changing problems. While our way of life was shaped by and is dependent on our environment—that is, our natural resources—we continue to change that environment, creating new problems.

As industry grew in Illinois opening new work opportunities in the cities, and as farms became mechanized requiring less farm labor, more and more people were drawn to metropolitan areas. Now more than 80 percent of Illinois residents live in urban areas. These sprawling cities and suburbs spread out over agricultural lands changing the patterns of land use. As a result there are new problems of water supply, drainage, water and air pollution, and waste disposal. And, there is a variety of space problems for highways, airports, and recreational areas. All of these in turn may affect soil erosion, woodlands, fish, and wildlife.

Concepts in Water Conservation

These changing problems point out two important concepts in conservation. First, they show clearly the interdependence of man and all natural resources—whatever happens to one affects all the others. Second, they show without doubt that in today's complex society conservation of natural resources is the responsibility of all citizens. Conservation is no longer just a farm problem; it is very much an urban problem as well. Certainly, conservation of water resources is important to each of us, young and old alike.

Without water, life as we know it could not exist. Protoplasm, the fundamental substance of which animals and plants are composed, is mostly water. Water makes possible our food, shapes our landscape, and affects our climate. It is a cleansing agent and a carrier of wastes. Water is a means of power and transportation, an ingredient in most manufacturing processes, and provides recreation.

Water, fortunately, is a renewable resource which constantly recycles itself. However, the total amount of water in the world is the same today as it was thousands of years ago, and so far as scientists can determine, it will be neither less nor more in the future.

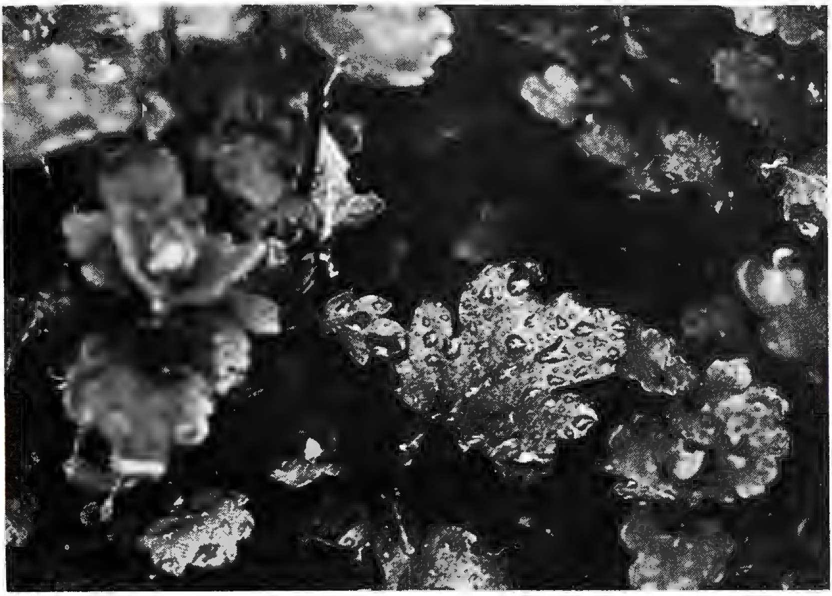
This means that, as the world population and our demands for water increase, water conservation becomes more important. We must use what we have more efficiently, use it again and again for many purposes, protect it from pollution and misuse, and find many ways to increase its usefulness. At the same time, we must remember that the flowing water we see knows no boundaries except that of its natural watershed (the unit of land from which all water drains into a single channel). Thus, planning in terms of a watershed is important to effective water conservation.

About This Booklet

This booklet discusses some of the important ways of conserving our water resource in Illinois. Of course, the first step in planning conservation practices is to know the resource—its nature and behavior, its amount and distribution. Then we need to know how the resource is used, how problems come about, and how we can try to solve them. Conservation needs and practices can be seen at many points along the way.

Our first chapter starts with the rather strange chemical and physical properties of water, which affect its behavior and use in so many ways, and discusses the importance of water in all living things. The second chapter traces the water cycle and describes Nature's processes that produce clouds, precipitation, evaporation, weather, and climate. This chapter closes with a section on how we measure water at various stages of its cycle.

The third chapter concerns the sources for our water supplies in Illinois and their quality, and the next chapter discusses important water uses and problems. A final chapter brings together information on agencies concerned with Illinois water resources and materials for further reading.



Drops of water—precious but peculiar

WATER'S STRANGE WAYS

Water is so ordinary that we sometimes forget its important role in the affairs of this planet.

In many ways water is a paradox. It is necessary to life, but living things can drown in it. It is so common we seldom think of it, yet wars have been fought over water and thriving civilizations have failed for lack of it. It is the most common substance on earth, found everywhere, always moving, its total never changing; but its distribution over land areas is so irregular in place and time that deserts and rain forests occur, and even areas of favorable distribution such as Illinois may have floods or droughts.

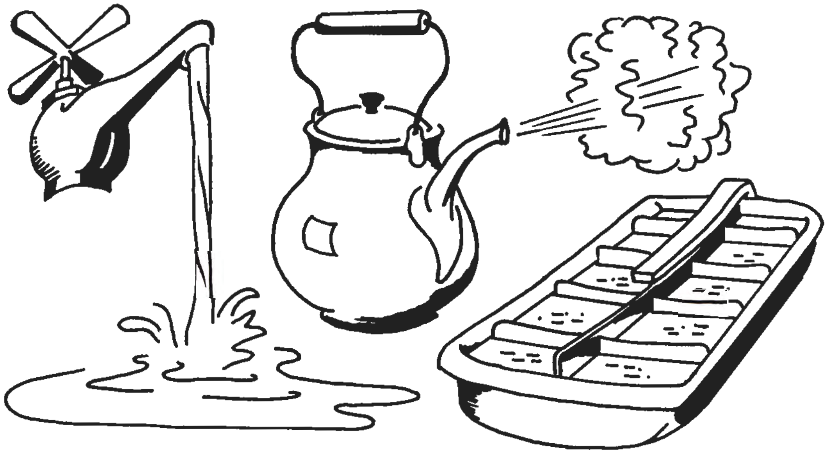
These large contrasts and the peculiarities of water which make its role important can be traced to the fact that water does not act like other substances. Indeed, water's rather docile appearance as a tasteless, odorless, and colorless substance is another contrast, masking its unique chemical and physical properties. Although these properties form a complex study that we must leave to chemistry, we need to look briefly at water's strange ways which affect the water we use every day.

Chemical and Physical Properties of Water

Water is an extraordinary chemical compound with its own peculiar pattern of behavior.

In nature it does not appear as the pure chemical compound of H_2O. Rather, it is most often a solution containing many dissolved and suspended substances. Water is a very stable compound and can dissolve almost any substance without a change in its own chemical makeup.

Water occurs in three basic forms, as a solid below 32 degrees Fahrenheit, a gas above 212 degrees, and a liquid in the temperature range between. Above its freezing point of 32 degrees, it can take either a gas or liquid form, but the liquid form does not exist above the boiling point of 212 degrees or below freezing. A single water molecule is composed of two hydrogen atoms and one oxygen atom which are so strongly attracted to each other that it is extremely difficult to break the bonds that hold them together. This is why a water molecule remains a water molecule even when its physical form changes to a liquid, a solid, or a gas. Water is the only common substance that occurs naturally in all three physical states.



Water's three forms—liquid, gas, and solid

Chemists find water strange also in that the freezing and boiling temperatures are much higher than for other substances of similar molecular structure. If water behaved like the others, there would be no liquid water at our earth temperatures, only steam. And, there would be no life as we know it since blood would boil in the body and plants would wilt and die.

Most substances contract and become heavier as they cool. Water follows the pattern to a point, but below 39 degrees Fahrenheit, it begins to expand and become lighter, and at 32 degrees forms ice which is so light that it floats. If water did not have this quirk of behavior, lakes would freeze from the bottom up and fish could not survive.

Water has a unique capacity to absorb and release energy in the form of heat. As many unhappy homeowners know, water releases tremendous energy when it freezes—enough to burst a water pipe. On the other hand, it must absorb enormous energy (heat) before its temperature will rise enough to boil—ask any impatient housewife waiting for a teapot of boiling water.

Because of this ability to take in and give off great amounts of *heat energy, water helps to regulate temperature extremes and climate.* Large bodies of water absorb heat on hot days and release heat on cold days. This also happens when there is moisture in the air and on the land surface. In contrast, on the desert where there is little natural moisture, temperatures go extremely high in the daytime but may drop below freezing at night.

Another property of water which distinguishes it from other liquids is its high surface tension. Mercury is the only commonly occurring liquid which has a higher surface tension than water. Simply speaking, the surface tension of water is its ability to cohere, that is, to stick to itself, and to adhere, or stick to solid substances.

The cohesive property of water is demonstrated when water drops from a faucet. Water molecules collect at the rim of the faucet and pull themselves together into a tight sphere when they begin to fall. Water takes this spherical shape because it is the most closely-knit formation possible. As the drop falls, pressure of the surrounding air modifies it, flattening its spherical shape somewhat. It is this cohesive property that gives water its stability, since only by great force can this surface be broken.

The adhesive property of water can be seen in a glass of water. The water level at the sides of the glass is higher than the level in the middle. The water molecules climb upward on the glass because of their ability to adhere to it, and as the molecules on the side climb, they lift the whole quantity of water to a slightly higher level. This process continues until gravity allows no more elevation. Finally, some molecules at the sides remain higher than those in the middle. Of course, the total ascent is instantaneous so that when we fill a glass with water, we can immediately see the slight crescent shape of the water level. It is this adhesive property that allows water's capillary action, by which it creeps up through the soil bearing nutrients to and through plants or moves our blood in full circle through the body.

Water in the Body

The human body and indeed all living organisms are dependent on water. Since nature made no provision in our body for storing water, we must live near a never-ending source of water.

Scientists believe that all life originated in the seas of long ago. Today, after millions of years, man's tissues are bathed in a salty solution reminiscent of that sea water. This solution lubricates muscles, tendons, cartilages, and bones.

Water is an essential part of the structure of cells as well as of the fluids in and around them. Shell-like complex molecular structures of water tend to enclose large protein molecules of the cells.

Every organic process occurs in the watery medium. Water solutions carry food to the cells and remove wastes. The transport of oxygen to the tissues and of carbon dioxide from the tissues to the lungs depends upon blood, which is about 80 percent water. All bodily processes of breathing, digestion, glandular activities, heat dissipation, and secretion are performed only in the presence of water solutions.

A refreshing drink—vital to all

Water constitutes about 65 percent of the total weight of the human body, varying slightly with individuals. We must consume about five to six pints of water daily from water-rich foods such as fruits, vegetables, and meats, as well as from drinking water and other liquids, to replace water lost through perspiration, excretion, and exhalation.

However, we cannot consume much more than this daily requirement of water. In the very complicated human body, water intake and loss must be precisely balanced, and the process must be repeated daily since there is no allowance for storage. Either too much or too little water can cause death, and even small imbalances, such as excessive perspiration in very hot weather, can cause illness or pain.

Without water and with only slight activity, a normal person in good health could survive a few days, perhaps up to a week. He could survive several weeks without food, if he had a minimum supply of drinking water.

Like the human body, all animal life requires water. The limits of the intake-output balance are not quite so restrictive in animals as in humans, however, and animal bodies are adapted to a great variety of environments. Thus, some animals have adapted to arid climates and desert life while others live in water. Each animal body has its own limits for water which must be met to survive.

Water for Plants

Plants too must have water, and their ways of using water as well as their water needs are even more varied than those of animals.

Land plants obtain most of their water by absorbing moisture from the soil through their roots and numerous fine root hairs. The root hairs are like thousands of microscopic soda straws sipping water from the ground. The water serves as a transport for plant nutrients. The stems of plants and woody tissues of the roots serve mainly as a support connecting the roots in the ground with the leaves reaching toward the sun.

Using the sun's energy, leaf cells transform carbon dioxide from the air and water from the soil into complex sugars and starches, releasing the by-product oxygen. This process, photosynthesis, is basic to all plant life—and thus to all animal life—for it is the only process in nature by which food is made from raw elements using solar energy. All green plants are engaged in this process.

Nearly all of the water absorbed by plants returns to the atmosphere by transpiration, that is, water leaves the green tissues as vapor. The quantity of water that transpires from a plant depends upon the air temperature and its moisture content, soil moisture, light, and wind. On a hot day in the country, one can feel an effect of transpiration. An area containing many green plants is actually cooled by the transpiration of plants. This cooling is much like the cooling caused by perspiration which occurs when water evaporates from the skin.

If the plant does not have a sufficient water supply, it wilts, the stomata or pores close, and transpiration stops. A severely wilted plant cannot continue photosynthesis because the closed pores prevent the exchange of gases in the air and the flow of water.

Nature at work—on a thundercloud

NATURE AT WORK

Water is neither manufactured nor destroyed. In one of its three forms as a liquid, gas, or solid, the amount of water in the world remains the same. The world's water resource is therefore limited; we can only try to make the best possible use of it.

We find the waters of the world in five forms. About 97 percent of it is salt water in the oceans which cover almost three-fourths of the earth's surface, and a little over 2 percent is frozen water in the ice masses and glaciers. The remainder, less than 1 percent of the total, consists of the water vapor in the atmosphere, the water under the ground surface, and the water in lakes and streams.

Thus, about 1 percent of all water is in constant motion, circulating from ocean to atmosphere and again to the ocean in an endless cycle that is called the water cycle, or hydrologic cycle.

The water resource that we use is constantly renewed by this cycle, but it is also constantly changing. To manage our water resource wisely, we need to understand Nature's processes that affect the amount and distribution of water and the means by which we can measure what we have.

Tracing the Water Cycle

Although the water cycle has no beginning nor end, it is convenient to start our discussion at the major storage area, the oceans.

Liquid water from the surface of the oceans is evaporated into the atmosphere as water vapor, a gas. The sun provides the energy for this evaporative process.

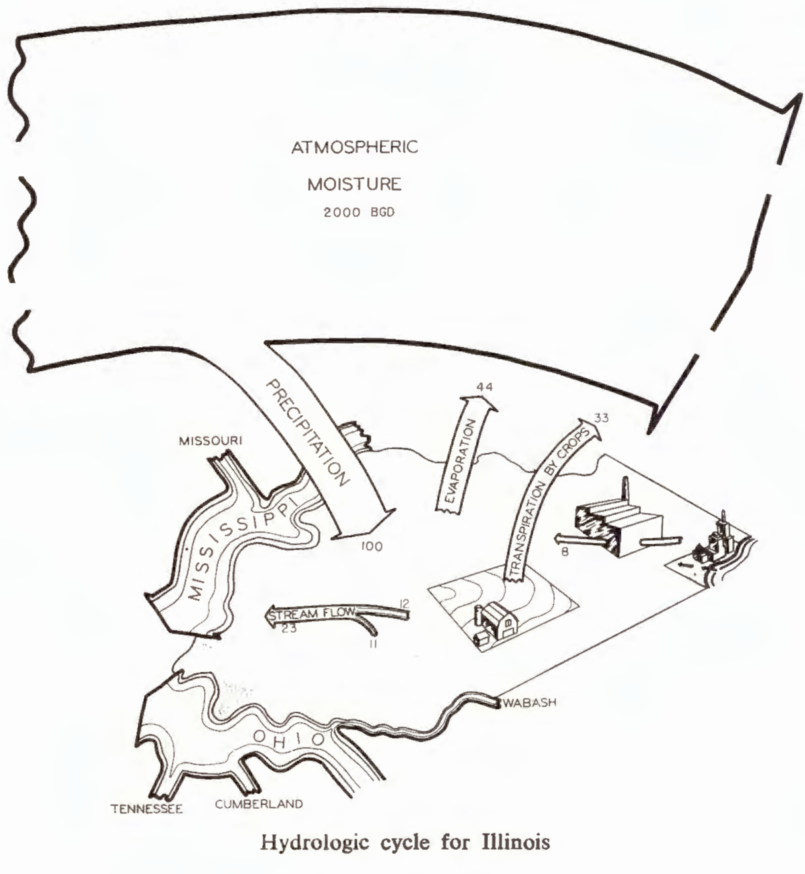
The water vapor in the air is lifted and cooled, eventually condensing to fall as precipitation either back on the oceans or on land areas. Precipitation may fall in the form of rain, snow, sleet, or hail.

Much of this precipitation evaporates, sometimes even before it reaches the surface, so that it circles directly back to the atmosphere; it may once more become precipitation, but it is lost for immediate beneficial uses by man. Another large portion is used by vegetation and transpired back to the atmosphere. Together, evaporation and transpiration account for about three-fourths of the original precipitation, which can be considered a bypass in the water cycle.

The remaining part of the water that falls as precipitation moves over and through the land areas of the earth, draining finally into channels that flow again to the ocean. Only this portion is available temporarily for man's use, held for varying times in streams and lakes or in layers of the earth's crust.

Thus, precipitation becomes the source of our usable water resources, and the great variability of precipitation largely accounts for the uneven distribution of water resources from place to place and in time.

Eventually, all water moves through the cycle, although at different rates of speed. It is estimated that water precipitated over an area and running off into a flowing stream completes its cycle to the ocean in a few days. Water soaking into the soil and percolating downward to become groundwater moves much more slowly. Very deep



Hydrologic cycle for Illinois

groundwater has been there for many years. Water in the ground is therefore held for our use for a longer time, as is the water caught in lakes or reservoirs. Because of this, both underground storage and reservoir storage are important means of conserving water.

Although in the water cycle the amount of atmospheric moisture which surrounds the earth is very large, only a small percentage falls at any one place as precipitation. This is illustrated in tracing the water cycle in Illinois, which is shown in the picture diagram.

It is estimated that an average of 2,000 billion gallons of water vapor daily passes over Illinois. But, the processes of Nature cause only about 5 percent of this moisture to fall on the state as precipitation.

This small percentage, however, constitutes an average of almost 100 billion gallons of precipitation for every day of the year in Illinois.

Nearly half of this precipitation, or about 44 billion gallons, evaporates from land and water surfaces and is lost to the atmosphere. Growing plants make use of another 33 billion gallons, which they then transpire back to the atmosphere. The remaining 23 billion gallons becomes streamflow and groundwater, for our use before it flows out of the State. In addition, we can share in the use of our surrounding fresh waters of the vast Mississippi and Ohio Rivers and Lake Michigan, which, as we shall see later, more than doubles our total usable resource. This is an immense amount of water—more than three times the present usage in Illinois and one-sixth of the water usage for all purposes in the entire United States.

Although our total water resource for Illinois is large, its distribution in time and place is not uniform. Precipitation varies from place to place, by season, and from year to year, and is affected from time to time by extremes—droughts and floods.

Precipitation variations from place to place are due in part to the State's great north-south length. Within this 385 miles of latitude, there are major differences in temperatures, storm tracks, and distance from the primary moisture source, which is the Gulf of Mexico. Thus, precipitation for a year averages about 46 inches in the Shawnee Hills of southern Illinois and decreases northward to about 32 inches in the vicinity of Lake Michigan.

The course that precipitation takes after it reaches any one area of the State, that is, whether it will run through or over the ground, also varies. It depends upon the previous moisture conditions, the temperature, the type of soil and plants present, and the topography. These factors affect the processes of evaporation, transpiration, seepage into the ground, and runoff; and the influences and natural interrelationships of these factors vary seasonally.

Cloud Formation

Cloud formation is the first step in the precipitation process.

All clouds consist of tiny droplets of water or particles of ice or both. These droplets or particles are formed when water vapor in the atmosphere returns to the liquid or solid state.

Funnel-shaped tornado cloud, center, an unwelcome cloud formation

The amount of water vapor that a given air mass can contain is dependent in part upon the temperature of the air. Warm air has a greater capacity for moisture than does cool air. Therefore, when air cools, it reaches its own moisture saturation point. Supersaturation occurs with further cooling and results in condensation; that is, the water changes from a gas to a liquid. Cloud droplets, then, are formed when an air mass has reached a temperature cool enough to trigger condensation.

The cloud droplets condense onto tiny airborne particles, or nuclei, which are the result of a variety of natural phenomena as well as industrial and other man-made processes. These condensation nuclei are either hygroscopic—that is, they take up and retain water readily—or nonhygroscopic. When the hygroscopic particles such as salts are present, condensation can occur much sooner than it does when nonhygroscopic particles are involved. Thus supersaturation and consequent condensation of the water vapor occurs at a point respective to the particular type of nuclei present.

The formation of these tiny droplets which constitute clouds is similar to the formation of water droplets on a glass of ice water. The air around the glass is cooled to its dew point and some of its moisture condenses onto the glass.

The process by which ice crystals, instead of water droplets, are formed is sublimation, in which moisture goes directly from a vapor into the solid state at below-freezing temperatures, with no intermediate liquid state. The factor of supersaturation is involved as in condensation.

Meteorologists point out three main methods by which an air mass can be lifted to an elevation where condensation can occur. First, winds rising to get over a hill or mountain may move warm air to a cooler part of the atmosphere. Second, when warm and cool air masses meet, the warm air rises because it is lighter than the cool air. Third, heating by the earth's surface can cause an air mass to rise since the heating makes it lighter.

The tiny cloud droplets that result from condensation can take many forms depending upon other weather conditions. The height of the base of the clouds above the earth's surface depends upon the temperature and the relative humidity. When the lower atmosphere is warm and moist, the cloud bases are low. Fog, a cloud which forms with its base at the ground's surface, can occur under these conditions. With warm, dry air as environment, clouds appear higher. Thus, billowy cumulus clouds often are seen on a hot summer day. These clouds can develop into churning, anvil-shaped cumulonimbus or 'thunderclouds,' which is the most important rain-producing cloud type in Illinois.

In general, cooler air is more stable than warm air and is conducive to the formation of layer clouds at all altitudes. These layer clouds extend over a great horizontal distance, whereas cumulus and cumulonimbus clouds develop vertically in a localized area. For example layer clouds may extend over several states, but a large cumulus cloud may cover only a small county.

The Precipitation Process

Although the process by which clouds produce rain is not completely understood, two theories are predominant in meteorology. One involves ice crystals and the other, collision and coalescence of cloud droplets.

In the ice crystal theory, the formation of precipitation droplets occurs when the equilibrium of a cloud is disturbed by the introduction of an ice crystal. A cloud is in equilibrium when the same number of molecules is leaving a given cloud droplet as is entering the droplet. The balance is disturbed as the recently arrived ice crystal begins to attract water molecules so that more molecules leave a droplet than enter it. The molecules attracted by the crystal freeze onto it. Thus, the ice crystal begins to grow at the expense of the droplet.

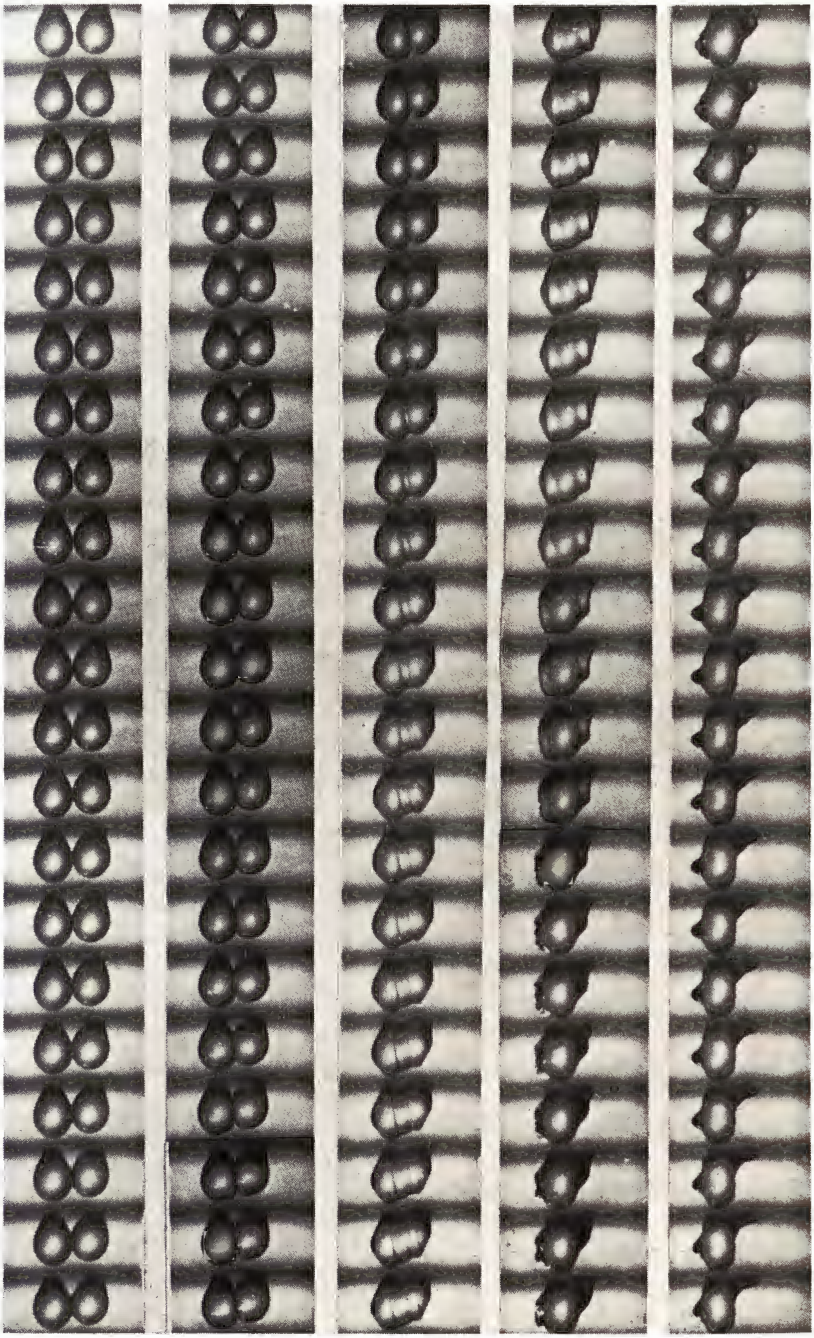
As the crystal grows it falls through the surrounding droplets, some of which freeze onto the crystal. So, the crystal becomes even larger. If the crystal falls through a layer of warm air, it melts, becoming rain. If it reaches the ground without melting, it is snow.

The collision and coalescence theory explains the formation of raindrops when ice crystals are not present in the cloud. This process begins when a large drop is introduced into a cloud. This large drop, which falls faster than the average cloud droplets, overtakes and collides with some of the droplets, and they may unite, or coalesce. Scientists have discovered that not all collisions result in coalescence. In fact, high-speed films have shown two drops bouncing off each other.

The source of these large drops which initiate the collision and coalescence process may be, according to three different theories, salt nuclei, electrical forces, or gravity. Some scientists point out that the source may vary with the circumstances, with one or a combination of the three factors being responsible for formation of the large drops.

Ice-crystal growth appears generally to initiate rain in the northern latitudes, whereas the coalescence process seems to be responsible for the formation of rain in the tropics. Both methods are thought to occur in the middle latitudes, which would include Illinois, especially during the warm months, and indeed both processes can occur in the same cloud.

Precipitation in Illinois may take other forms in addition to rain and snow. If raindrops, after they have been formed by either ice-crystal or coalescence processes, fall through layers of very cold air, they freeze or partially freeze and fall as sleet. If raindrops should be caught in the very turbulent air of a thunderstorm and tossed repeatedly into cold moist air, layer upon layer of ice forms on each droplet, and they fall as hail. What we know as freezing rain is formed by rain freezing on cold objects.



Laboratory camera catches sequence of colliding and coalescing raindrops

Large hailstones damage property and crops

Many questions about rainfall remain. The processes are inefficient. In humid areas, approximately 10 percent of the available water in the average thunderstorm reaches the ground as rain; in arid regions, the percentage is less. Large clouds may form but produce no rain.

Basic research into the composition and behavior of clouds and their ability to produce rain is being continued by scientists in field studies and in the laboratory. Improved tools of research, such as radar, aircraft, weather satellites, special cameras, and cloud chambers, are now available for these studies, and computers make it possible to handle and study great masses of information. Greater knowledge of the processes of cloud formation and rainfall initiation is essential for future weather modification work, by which scientists hope to assist these natural processes to be more efficient, thereby increasing the usefulness of our water resource.

Weather and Climate

Weather, and consequently climate, is like bread. There are basic ingredients, but the texture or type of product depends on the proportions of the ingredients. Sun, air masses, and moisture combine to form weather and climate. The sun is the leavening of the mixture, providing the creative and modifying force which shapes the loaf.

An air mass is a very large body of moving air having nearly uniform temperature and humidity at any given level. Air masses may be dry or moist and hot or cold. They assimilate water that is evaporating from land areas or bodies of water over which they pass. Heating of an air mass occurs largely by the sun and in some cases by very warm land areas.

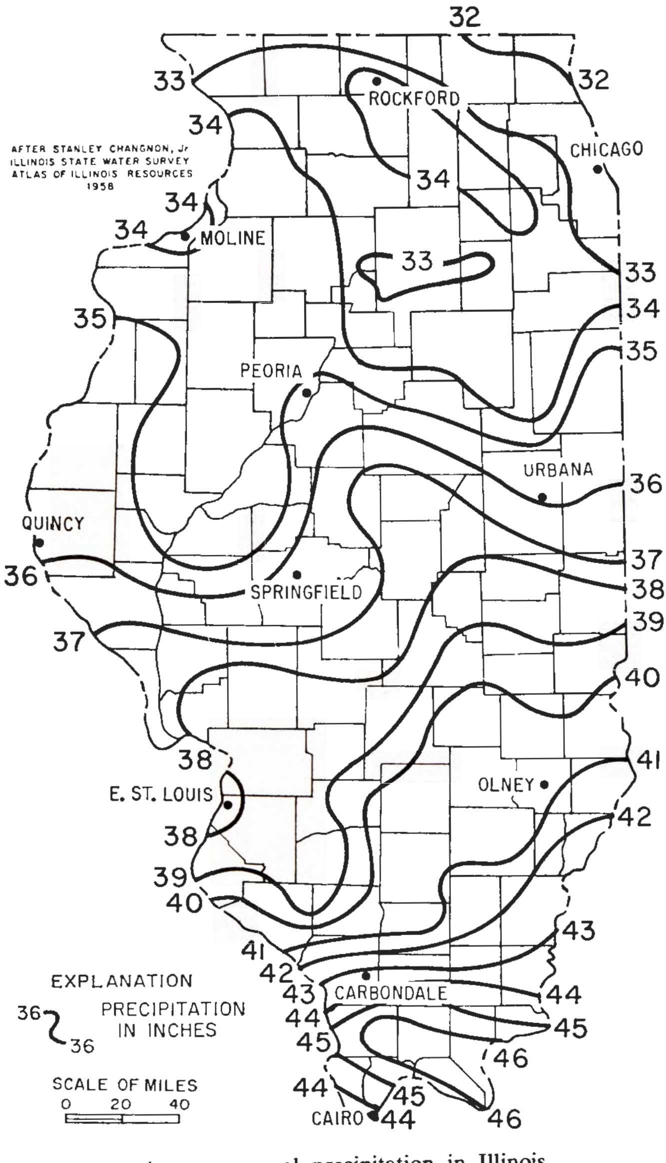
The movement and behavior of air masses are affected by topographic features, pressure, and winds. Mountains, for example, force air masses to rise, often providing the possibility of precipitation if moisture is adequate. Although the earth's rotation accounts for large-scale wind motions, most local wind is caused by pressure differences resulting from the interaction of warm and cool air masses. When cold and warm air masses interact, they tend to move in a circular path with the cold air pushing the warm air upward and sideward.

Weather in Illinois is controlled by latitude, continental location, winds, and storms resulting from the interaction of various air masses which pass over the State. Latitude and continental location account for the way in which the sun's rays strike this particular area with respect to its position from the equator.

The climate of Illinois features generally hot summers and cold winters through the State. However, because of the north-to-south length of the State, there is considerable variation in both temperature and precipitation from north to south. The north has generally cooler and drier weather than the south, but the greatest differences between the two areas occur in winter.

In Illinois, the temperature varies from north to south in all seasons, but the difference is about 16 degrees in winter and only 8 degrees in summer. During winter in the north, below-zero temperatures are not uncommon and soil freezes to a depth of about 36 inches; the south averages one day of zero-temperature per winter and soil freezes to a depth of only 8 to 12 inches. The freeze-free period, or growing season, is about 160 days in the north but about 190 days in the south. Throughout the State, changes in temperature may be great from day to day and from week to week. Normally, the hottest month is July and the coldest month is January.

Variability is the most significant characteristic of the annual precipitation in Illinois, which ranges from 32 inches in the northeast to 46 inches in the extreme south. It also varies from year to year in all parts of the State. During the colder half of the year, October through March, precipitation ranges from about 12 inches in the north to 23 inches in the south. However, in summer there is much less difference, and precipitation for April through September ranges from 20 to 24 inches from north to south. February is the driest month through-



Average annual precipitation in Illinois

out the state. But the wettest month is usually March in the south, May in south-central and eastern Illinois, and June in the remainder of the State.

Snowfall is usually not a significant part of our total precipitation in Illinois. It produces about 10 percent of the year's total in northern Illinois and only 2 or 3 percent of the total in the south. Snowfall from year to year is even more variable than rain. In the north, annual snow averages 33 inches, but the total has been as low as 10 inches and as high as 65 inches in a year. Southern Illinois averages 9 inches of snow a year, but has had less than 1 inch and more than 50 inches in a year.

Storm systems which bring widespread precipitation through Illinois occur mostly in the winter and spring. Summer storms cover a smaller area, but the heat and high moisture content of the atmosphere promote intense localized thunderstorm activity, which occasionally is accompanied by hail and windstorms, or even tornadoes.

Thunderstorms produce more than 70 percent of the normal precipitation in the warm months. Thunderstorms are highly variable, which is the chief reason for the great difference in precipitation in various areas of the State and at various times during a given season. Thunderstorms often occur when a cold front moves in, that is, when a mass of cold air advances upon a mass of warm air.

Measuring Water

A logical question might be: how do we know that an average of about 100 billion gallons of water falls daily on Illinois, or how do we know that about 23 billion gallons daily, on an average, flows in the rivers and streams? It is true that exact amounts of water in each phase of the water cycle cannot be measured. No one, for example, has measured each gallon of the 77 billion gallons that leaves the State daily through evaporation and transpiration.

Yet, certain phases of the water cycle can be measured, and the unknown quantities can be calculated from these amounts and from the known physical area of the State.

We must know the nature and extent of our total water resource in order to use it wisely. As more and more water is needed, increasingly accurate measures of water resource elements become important.

Precipitation is measured with standard raingages and snowgages at official U.S. Weather Bureau stations throughout the country, including 285 stations in Illinois.

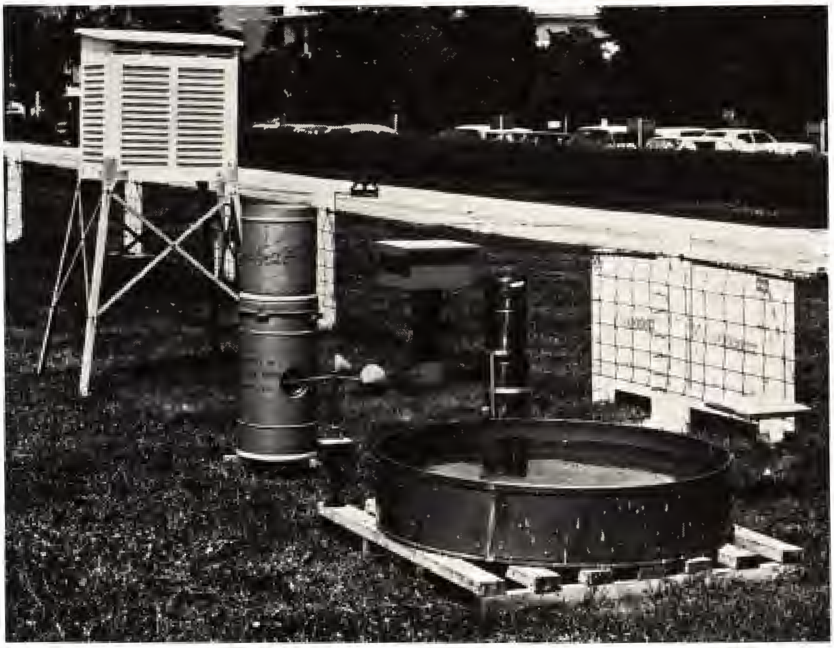
Temperature, wind, and a variety of other weather elements affecting rainfall and climate also are measured or observed at these stations. Observer-reports, in combination with information from weather radars and weather satellites, are used in making weather forecasts.

Observer reads chart from recording raingage, which is protected by metal wind shield

Continuous records of weather elements are used in determining the climate of an area and any changes in climate that may be taking place, an important part being the precipitation regime that affects our available water resource.

The Morrow Plots Weather Station on the Urbana campus of the University of Illinois is one of the Weather Bureau's Bench Mark Stations for the study of past and future climatic changes in the United States. This Illinois Station, established in 1888, was selected as a Bench Mark Station among some 15 east of the Rocky Mountains because of its long continuous records at the same site. Its records include 14 daily measurements of different elements, many measured continuously by recording instruments.

In addition to weather stations, five dense raingage networks are operated in Illinois by the State Water Survey for scientific research concerning precipitation. The many gages in these networks are uniformly spaced in a geometric pattern so that the amount of rainfall (and its variability) for a given number of square miles can be studied statistically.



ABOVE: Morrow Plots Weather Station. BELOW: Station equipment, left to right, includes standard white shelter for temperature gages, recording raingage, and evaporation pan with wind indicator. Table-like stands in the back row measure hailfall.

Such studies provide very detailed information concerning, for example, the probabilities of average and extreme (high and low) precipitation and runoff conditions, for a specific area and period of time. This material is valuable to engineers, agriculturists, and others concerned with designing such things as city or farm drainage systems, highway culverts, flood controls, or water-supply developments.

Streamflow is measured at stream gaging stations located at key points on flowing streams. A stream gaging station can be identified by the corrugated metal or concrete towers that house the measuring equipment, often located near highway bridges. At each station location, engineers measure the width and depth across the stream and then place flow meters in the water, from which they can calculate the amount of water flowing at that point for a given period of time.

Stream gaging station on Bluegrass Creek at Potomac

Most stream gaging stations in the United States are operated by the U. S. Geological Survey, to assure a uniform system of measurements, and stations often are sponsored or supported on a fifty-fifty cost-sharing basis by state, local, or other federal agencies.

In Illinois, the State Water Survey sponsors some 150 permanent or full-time stream gaging stations on major streams, and may sponsor other stations for short periods for research. The average amount of streamflow over a year for Illinois streams has been calculated from these stream gage records.

Of particular importance from studies of these records is knowledge of how long the flow of a particular stream can be expected to stay at very low, average, or flood stages, and when these varying stages might occur. Such knowledge is important in many ways. It can be used, for example, to determine if the stream can be counted upon to supply enough water for a water-supply reservoir throughout the year, or to determine whether flood-control structures are needed and feasible.

Measuring evaporation and transpiration is also important in assessing our total water resource, for these amounts represent losses in that the water returns to the atmosphere as a vapor and is not immediately available for reuse by man.

Evaporation from water surfaces is calculated by placing water in a specially designed evaporation pan and measuring the amount lost over a period of time. Nine weather stations in Illinois maintain standard evaporation pans, and studies of these records have provided general estimates of evaporation for regions of the State. However, evaporation is affected by temperature, wind, and the amount of moisture already in the air. These and other factors must be considered in the rather complex computations of evaporation from a lake or reservoir surface.

The amount and the variability of evaporation from lakes in Illinois have been determined by Water Survey hydrologists. These measures are very important in determining how much water will be available for use from a water-supply reservoir. Normally in Illinois evaporation from lake surfaces is balanced by direct precipitation over the lake, but the variability of both evaporation and precipitation makes knowledge of exact losses important, especially as our demands for water increase.

Evaporation from land surfaces cannot be measured accurately, but it can be estimated when rainfall and streamflow are known. Transpiration from plants is likewise difficult to measure, and researchers are still seeking better instruments to give direct measures. The most common instrument used is the weighing lysimeter, but it is difficult and expensive to operate. Plant transpiration is sometimes estimated from measures of soil moisture losses. Soil moisture can be measured by weighing soil samples, drying them, and reweighing; however, neutron probes are now available which can measure soil moisture in the field.

In addition to these measures of our water resource in the various phases of the hydrologic cycle, a very detailed accounting system is necessary for each specific water-supply source and for each of the many uses of water.

Inventories of existing and potential reservoirs and lakes, and of existing and potential yields of groundwater, provide information on how much water is available for use. Water censuses, taken from the records of municipalities and industries, provide average amounts of water used in homes, industries, and businesses. Only through such detailed accounting can we manage our water resources wisely for today and the future.

Streams are important water supply sources

WATER SUPPLIES—
THEIR SOURCES AND QUALITY

Looking again at the water cycle in Illinois we see that 23 billion gallons of the 100-billion-gallon total average daily precipitation over a year becomes streamflow and groundwater—the water that is available for our use before it flows on out of the State. In addition, we share in the use of immense adjacent waters—Lake Michigan and the great border rivers, the Mississippi, Wabash, and Ohio. This additional share of water brings our average grand total supply to around 50 billion gallons per day.

Although this is an immense amount of water, and more than three times the present usage in Illinois, we must remember that this water is not uniformly distributed day by day or from place to place, and is not uniform in quality. Let us look more closely at the distribution of this total supply.

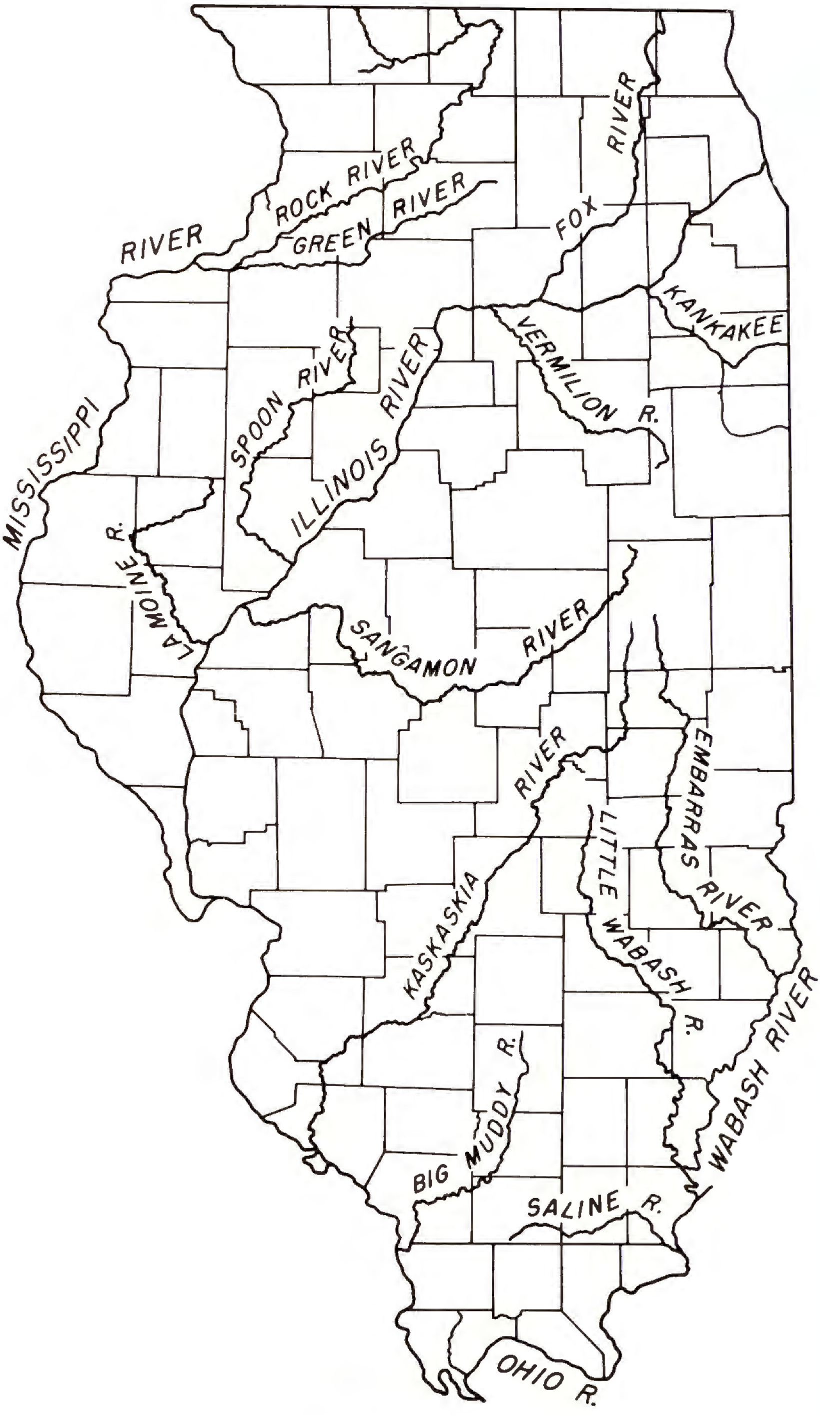
Part of the precipitation that falls on the State runs off into flowing streams or surface depressions such as lakes and reservoirs, natural or man-made. This runoff water then becomes streamflow, and the rivers, streams, lakes, and ponds that it fills are called our surface water resources.

Another part of our precipitation sinks into soil surfaces, some serving the important needs of vegetation as soil moisture and some percolating deeper into the ground becoming our groundwater resources.

Thus, surface water and groundwater are the two major sources from which we develop water-supply systems that directly serve homes, cities, and industries.

The Surface Source

Illinois is almost an island, in a sense being nearly surrounded by fresh water. Along its western border flows the mighty Mississippi and to the south and east are the Ohio and Wabash. Lake Michigan lies to the northeast. This is far from all, for large supplies of water are readily available within the State from great rivers such as the Rock, Illinois, Kaskaskia, Embarras, and Big Muddy. In addition, there are numerous smaller ones. Altogether, Illinois has some 2,700 interior streams.



Major streams in Illinois

For many purposes, water can be used directly from the streams, but streamflow is highly variable. Therefore, it becomes important to store runoff during high flow for use during dry seasons and droughts.

Streamflow

In Illinois runoff in the form of streamflow varies by area in much the same pattern as precipitation. The average annual streamflow if spread over the State would be about 9.7 inches, but it varies in depth by area so that it would be about 15 inches a year in the south and 8 inches in the north.

The higher runoff in southern Illinois, in conjunction with more rolling or hilly land surface, lends itself well to the development of impoundments. Nearly all large communities in the southern third of the State rely on reservoirs for their municipal water supplies, as do several in central Illinois.

Streamflow, like rainfall, also varies in time. To some extent these variations are seasonal, but there are wide deviations from the average in any season. In general, northern Illinois' smaller streamflow is less variable and therefore more dependable than the streamflow in southern parts of the State. In other words, streams in northern Illinois generally flow year round and have fewer extremely high or extremely low flows; southern Illinois streams may often go dry in summer or dry periods but may carry large quantities of water and frequently flood in wet periods.

Besides the seasonal and day-to-day changes, we have occasional extended periods of extreme weather conditions which bring drought and flood. Such extremes are studied intensively, for they are important guides to planning and design for water conservation and control.

We have improved or expanded our natural sources of surface water by impounding them in reservoirs, which are often used for soil and water conservation and for recreation as well as for water supply.

Reservoirs and Lakes

Illinois now has more than 900 bodies of water which may be classed as lakes or reservoirs. These are within the state boundaries and exclusive of Lake Michigan. Of these, 386 have a surface area of more than 40 acres and together contain more than 82 percent of the total water stored in reservoirs. In addition, Illinois has numerous smaller lakes and nearly 58,000 farm ponds of less than 6 acres surface area. Small lakes and ponds are important to land and water conservation in Illinois because they not only store water that can be used for water supply, livestock, recreation, and fire protection but also help protect land from erosion.

Natural lakes in Illinois are primarily in the northeastern portion of the State and are the result of the last glacial periods. Most of these are in the Fox Chain-O-Lakes region in Lake and McHenry Counties. Other natural lakes occur along the Illinois River, or in limestone sink holes near the Mississippi in southwestern Illinois.

Man-made lakes or reservoirs have been developed throughout the State for various purposes. Some of the more notable are Crab Orchard Lake, Lake Springfield, Lake Decatur, Lake of Egypt, Lake Taylorville, CIPS Lake, Little Grassy, Raccoon Lake, Devils Kitchen Lake, New Mattoon Lake, and Lake Vermilion.

Further development of reservoirs in the State is being explored and in some cases is under way. Seven large reservoirs for Illinois are under construction or being planned by the U. S. Army Corps of Engineers. Carlyle Reservoir on the Kaskaskia River in Clinton County is nearing completion. It is the largest of these new reservoirs, having a

Thousands of farm ponds in Illinois add to surface water resources capacity of 233,000 acre-feet. (An acre-foot is the amount of water that would cover an acre of land to a depth of one foot.) Carlyle will be about three times larger than Crab Orchard Lake, which has been the largest impoundment in Illinois. Construction has begun on Shelbyville Reservoir in Shelby County, also on the Kaskaskia River, and on Rend Lake on the Big Muddy River in Franklin County.

Other Corps of Engineers projects in various stages of design are Lincoln Reservoir on the Embarras River near the Coles-Cumberland County line, and Oakley Reservoir on the Sangamon River in Macon and Piatt Counties. Being planned are the Louisville Reservoir on the Little Wabash River in Clay County, and Helm Reservoir on Skillet Fork in Marion County.

All of these Corps of Engineers projects have been planned to serve at least four purposes—flood control, water supply, recreation, and water quality control. The three larger ones, Carlyle, Shelbyville, and Rend Lake, have additional purposes for navigation and fish and wildlife conservation.

Illinois also has a large potential for the development of additional impoundments. Approximately 800 sites for potential reservoirs of

Water is conserved through reservoir storage

larger than 40 acres surface area have been identified throughout the State. If fully developed, these potential reservoirs could provide six times the water storage of existing reservoirs, lakes, and ponds. Again, the distribution of potential sites is not uniform over the State. Streamflow, topography, and geology are more favorable for reservoirs in southern and many central portions of the State, but as we shall see in the next section, northern Illinois has greater groundwater sources.

Earlier we mentioned that the average annual streamflow is equivalent to a depth of about 9.7 inches over the State, and that part of this water can be used directly from streams. However, because this streamflow varies greatly from time to time, as well as from one area to another, we need to store part of it when flows are high in order to make better use of the resource and to have dependable amounts throughout the year.

Making better use of this streamflow can be seen in the following figures. We now store in existing lakes what would be 0.44 inch of water over the State, and Corps of Engineers projects mentioned would add 0.36 inch of water. But, the potential reservoirs, if fully developed, could add 2.85 inches for a total storage of 3.65 inches of water over the State. To use another term of measure, we could increase our water storage in reservoirs from the present 1.3 million acre-feet to a total of about 10.3 million acre-feet.

In the future as communities strive to meet growing demands for water, reservoir storage will be an increasingly important means of conserving water, since it is one way of actually enlarging our usable surface water resource.

Lake Michigan

In addition to streamflow within the State and our great border rivers, our surface water resources include water from Lake Michigan. This is an abundant source of water which is the supply for the Chicago Water System that serves the immense needs of that city and some 70 suburban communities. Lake Michigan is a part of the Great Lakes system, which, according to some authorities, contains about 57 percent of the world's fresh surface water. Although Lake Michigan provides a most fortunate source of water for this Illinois metropolitan area, the amount that can be withdrawn from the lake during a year has been limited by law and great vigilance is required to protect the lake from pollution so that it may be maintained as a satisfactory source for the future.

The Underground Source

That part of our precipitation which seeps downward through the soils to become groundwater provides Illinois with another large source of water.

Although it is easy to think first of rivers and lakes as water resources, this unseen source is sizeable in Illinois. Engineers estimate that it could supply as much as 7 billion gallons of water a day, which would be 21,500 acre-feet per day. In conserving water, Nature's underground storage system has some advantages over surface storage in that the water does not evaporate and is protected from much contamination.

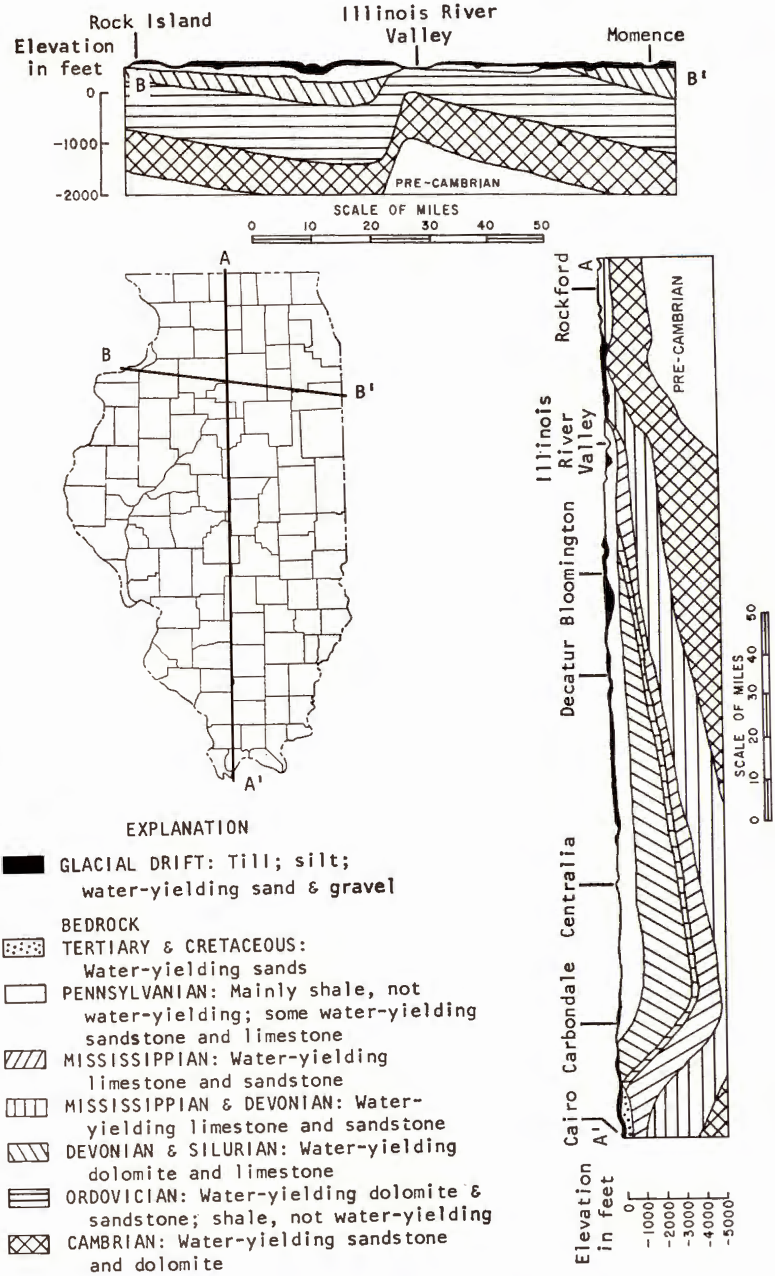
Groundwater is the source of water supply for almost all rural residents in Illinois, for the majority of our towns and cities especially in northern Illinois, and for many industries. In many areas it is a resource of particular importance because of its quality and economy.

Although our total groundwater resource is large, it is unevenly distributed over the State. By fortunate circumstance, groundwater is most abundant in the northern part of the State where surface runoff is less and where more generally flat topography does not offer as many favorable impoundment sites. The location, movement, amount, and quality of groundwater are related to the State's geology.

Geology

Granite of very remote geologic age underlies most of Illinois, but it is hidden everywhere by hundreds of feet of younger rocks. These younger rocks were originally deposited as sediments—sand, clay, shell fragments, or lime mud—in ancient oceans that covered all or parts of Illinois. The sediments were later hardened into firm, layered rocks, which we know now as shales, sandstones, and limestones.

These layered sedimentary bedrock formations, from tens to hundreds of millions years old, were originally relatively flat beds. However, they eventually were warped, and some were fractured or faulted. Erosion by the action of running water, ice, or wind caused additional irregularities in the bedrock. Soft shales and sandstones weathered away rapidly, while hard sandstone and limestone formations resisted erosion and remained to form ridges and hills on the bedrock surface. Bedrock formations of sandstone or limestone are important sources of groundwater, but its occurrence and movement are greatly affected by these irregular geologic features.



Cross sections show differing geologic features in Illinois

Beginning some thousands of years ago, the sedimentary rocks in Illinois were buried under deposits left by the great glaciers, which moved in from the northeast from Canada and spread over most of the State. The glaciers covered all but a small area in extreme southern Illinois and the northwestern corner, mostly Jo Daviess County.

The unconsolidated deposits left by the glaciers, which we call drift or glacial drift, were transported by glacial ice and its meltwater, and by wind. They are the parent materials for most soils in Illinois. There were several stages of glacial advances and melting, which left a variety of glacial deposits and land forms in Illinois. Drift varies from a few feet to more than 500 feet thick, but is thickest where the glaciers buried old valleys or built moraines and where several glaciers occurred. Sand and gravel layers in these glacial deposits are important sources of groundwater.

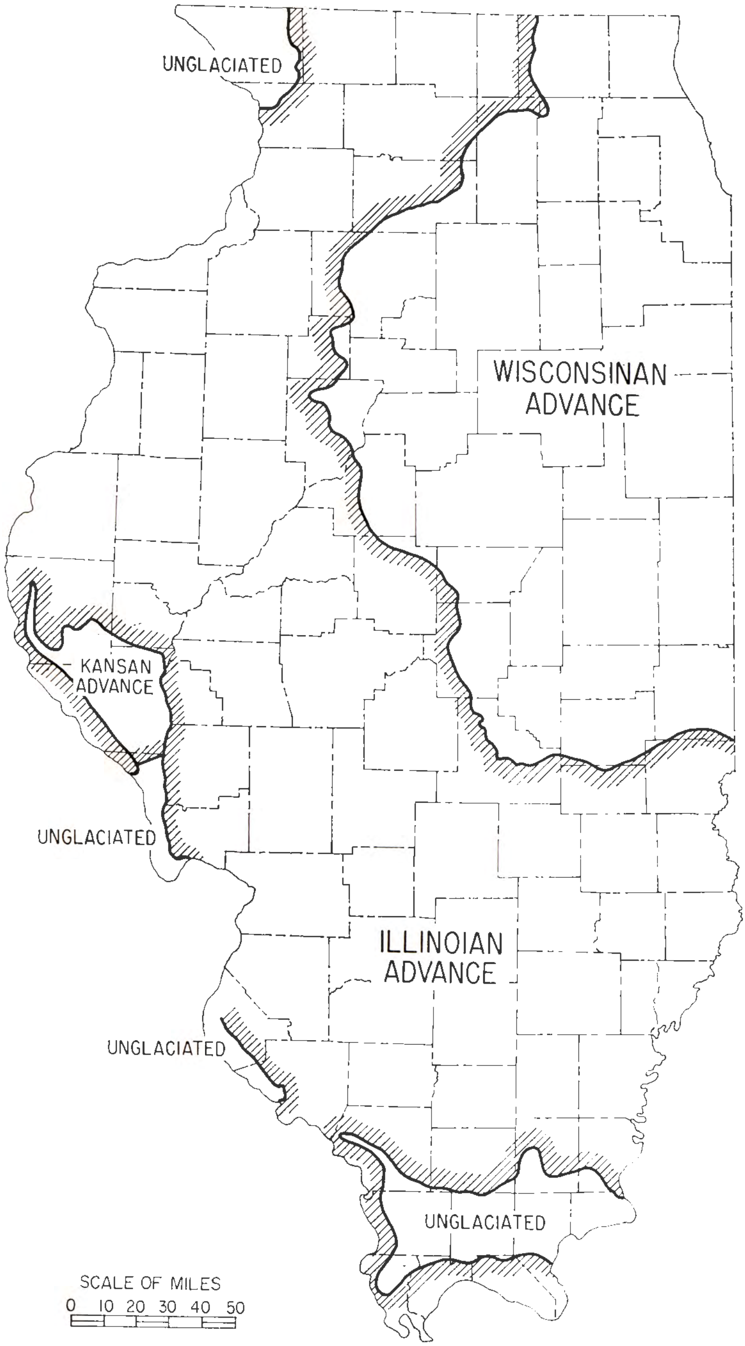
Occurrence and Movement

How does water occur and move through the ground? Part of the water that enters the ground is held in soil layers near the surface and is used by vegetation. The rest filters slowly down through the ground until it reaches a level where all available voids are completely water-filled. Water contained in this zone of saturation is groundwater, and its upper surface is the **water table.**

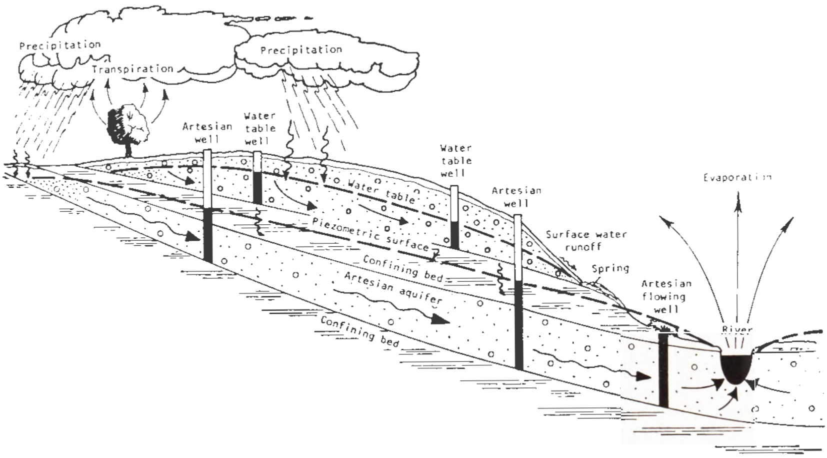
In unconsolidated deposits, water fills the voids between the grains that make up the formations. In bedrock formations, water may be contained either in the spaces between partially cemented grains of sandstone or in the fractures or solution cracks of limestone or dolomite (a limestonelike rock that is rich in magnesium).

A saturated formation of sand, gravel, sandstone, limestone, or dolomite that is capable of yielding water to wells in usable quantities is called an **aquifer.** However, the water-yielding capacity of aquifers varies greatly. Other earth materials such as silt, clay, and shale may contain abundant water in the minute pores between grains, but they retard movement of the water to such an extent that it cannot flow freely into a well. These dense layers may occur above or between aquifers and affect the movement of water.

Usually aquifers are regularly recharged (refilled) by rainfall occurring directly on the soil surface or by infiltration from adjacent streams or lakes. (Connecting aquifers may also supply water to streams, so that streams continue to flow during dry seasons. It is such availability of groundwater that accounts for the more stable streamflow



Movement of glaciers over Illinois. Earlier glaciers, the Kansan and then the Illinoian, covered most of the State. The later Wisconsinan glacier advanced only over north and east areas.



Water cycle and movement of groundwater

in northern Illinois streams.) The rate of recharge of an aquifer, whether by rainfall or infiltration or both, often determines whether groundwater withdrawal through wells can be maintained safely for a long period of time.

Sand and gravel aquifers in the glacial drift most often are recharged directly by local precipitation. If the drift aquifer contacts a bedrock aquifer below it, the water may move downward to recharge the bedrock aquifer. However, if a layer of dense material separates them, the downward movement of water is impeded. When such dense layers (called confining beds) are present, most of the water reaching the bedrock aquifer may come from a distant recharge area where the confining beds no longer exist or where the aquifer formation crops out at the land surface.

As an aquifer slopes downward from a recharge intake area and is confined beneath dense layers, the weight of the water at higher levels in the aquifer exerts pressure on the water in the confined area. This then becomes a confined or **artesian** aquifer. When a well penetrates an artesian aquifer, the pressure forces the water to rise in the well above the top of the aquifer. Many of the first artesian wells in northern Illinois flowed freely at the ground surface without pumping, but as more wells were drilled, the pressure was lessened so that the water does not rise as high and must be pumped to the surface.

Groundwater moves under the influence of gravity or other pressure differences from recharge areas to discharge points of lower pressure.

Points of discharge may be springs, lakes, streams, swamps, drainage tiles, or pumping wells. The movement toward discharge points may amount to only a few hundred feet a year in unconsolidated materials such as drift and to only a few feet a year in sandstone formations. Water may be held in bedrock aquifers for many years.

Location of Groundwater Supplies

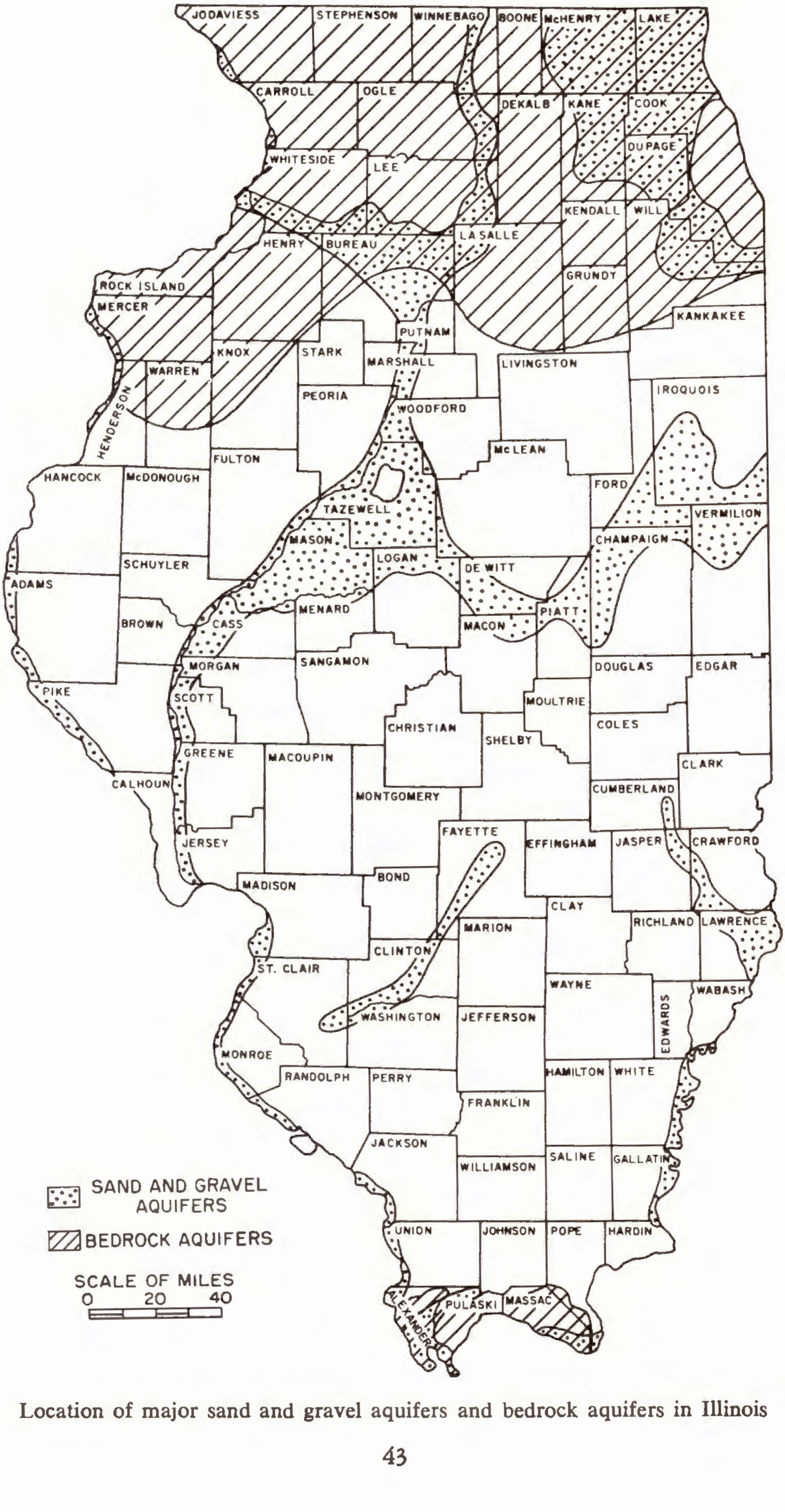
In Illinois, groundwater supplies are developed from both sand and gravel aquifers and from bedrock aquifers, but these are not uniformly distributed because their occurrence is determined by geologic features.

Sand and gravel aquifers in the glacial drift are prevalent through most of the State, and altogether add up to the greatest potential yield of groundwater, almost twice the amount available from bedrock aquifers. This is primarily because the sand and gravel aquifers have a higher rate of recharge. However, these aquifers vary greatly in size and yield capabilities.

Major sand and gravel aquifers, that is, those capable of providing a water supply large enough to serve cities or large industries, are located in only three general areas in the State. Most of these are in alluvial deposits that lie directly adjacent to the Mississippi, Illinois, Ohio, and Wabash Rivers. Some major aquifers are located in the buried Mahomet valley in east-central Illinois and in the valleys of the Kaskaskia, Little Wabash, and Embarras Rivers. Others are scattered throughout large areas of northeastern and central Illinois which were covered by several glaciers and thus have thicker glacial deposits.

Minor or thin sand and gravel aquifers may be found in much of the rest of the State, but may be difficult to locate. Further, these yield only small amounts of water, perhaps enough for a farm home and livestock or for a small town or light industry, and the supply may not be dependable in dry seasons. The least favorable areas for water supplies from sand and gravel aquifers are in western and southern Illinois where the glacial deposits are very thin and in the nonglaciated areas.

Bedrock formations are favorable aquifers in the northern third of Illinois where drinkable water supplies are obtained to depths of 1,500 feet or more. However, just south of the Illinois River these bedrock formations dip southward to a much greater depth in the spoonlike depression called the Illinois Basin, which has its center in the White County area of southeastern Illinois. At greater depths the groundwater from these rock formations becomes highly mineralized



Location of major sand and gravel aquifers and bedrock aquifers in Illinois and is not drinkable. Some of these brine waters, however, are important sources of water for water-flooding operations in oil fields in southern Illinois.

In the northern third of the State, large quantities of groundwater for industrial and municipal use are withdrawn from wells in the deep sandstone aquifers of Cambrian and Ordovician age and from the shallow dolomite aquifers of Silurian and Ordovician age. In the southern two-thirds of the State, where the glacial drift does not provide more suitable aquifers, small water supplies are developed from thin sandstone and limestone beds in rocks of Pennsylvanian and Mississippian age. In a small area in extreme southern Illinois, somewhat larger or moderate supplies of groundwater may be withdrawn from wells in creviced limestones of Mississippian, Devonian, and Silurian age.

Some of the deep artesian sandstone aquifers in northern Illinois are considered to be the best aquifers in the State because of their consistently high yields. Deep sandstone wells in that area have been prolific sources of good quality water for over 100 years. However, concentrated heavy pumping in some areas has seriously affected these sources.

Shallow dolomite rocks are also important large aquifers in northern Illinois, although the yields of wells are inconsistent. For example, one dolomite well may produce much water while a similar well nearby produces so little that it must be abandoned. This happens because the water in dolomite or limestone rocks, as we noted earlier, is in fractures or channels which have been formed in irregular sizes and patterns. However, dolomite aquifers are a great potential source in this area because they are near the surface or frequently are connected to glacial drift aquifers and thus have high rates of recharge.

Groundwater Conservation Features

One of the important steps for conservation of our groundwater resources is careful planning of well-field developments. Such planning must be based on sound knowledge of the particular characteristics and capacities of the aquifers present, and fortunately research in the past few years has given hydrologists and engineers scientific methods for obtaining such knowledge.

Wells drawing water from the same aquifer must be carefully spaced so that they do not interfere with each other, and the amount of water pumped from wells must be regulated according to the characteristics and recharge capability of the aquifer so pumpage of that amount may continue over many years. Also important in groundwater conservation is the protection of aquifers from contamination from the surface, which is particularly important for aquifers near the surface.

Heavy pumping can sometimes be offset by artificial as well as natural recharge. Stream water, if it is of suitable quality and quantity, can be used to replenish artificially a nearby sand and gravel aquifer. The surface water is pumped into pits or wells that touch the aquifer and is allowed to filter directly into the aquifer. Such artificial recharge using Illinois River water has been successfully operated at Peoria for over 15 years, and has served to stabilize and make possible the continued use of groundwater supplies that had been overpumped. In artificial recharge, great care must be taken to prevent the entrance of silt or pollutants that might clog or contaminate the aquifer.

Water Quality

The use of water supplies from our surface and groundwater sources depends not only on their location and amount but also on quality. It is not always enough to know that the supply is drinkable. The amount and the kind of minerals the water contains are also important, and no one combination of substances will suit every use.

The water quality that we speak of here is the mineral and chemical quality of water sources, not the sanitary quality. In Illinois, carefully enforced regulations ensure that all public water supplies have satisfactory sanitary quality for drinking and general domestic use, and the problems of protecting our water sources so that safe standards may be maintained will be discussed later. Actually, mineral quality is sometimes a part of those problems.

In an earlier chapter we mentioned that one of the properties of water is its ability to dissolve minerals and other substances. The degree to which minerals are dissolved depends upon the type of mineral with which the water comes in contact, the time of contact, and in some cases the presence or absence of dissolved oxygen.

The 'contact' minerals in groundwater are related to the geologic formation. The minerals in surface water are generally those of the surface soil, although many streams are at times fed by groundwater. Other minerals are added though public, industrial, and agricultural use of water.

Illinois Resource Quality

Water in Illinois is usually mineralized to a degree, is hard, and may also contain some form of iron or suspended matter. Methods are now available to modify or remove the dissolved and suspended components in water to the extent that any water can be made suitable for almost any purpose. Costs may exceed the economic benefit, however, and the public and industry alike must be alert to this problem as new sources of water are developed and old sources expanded.

As was noted in the discussion of groundwater sources, the quality of groundwater can vary widely by aquifer source, by depth, and by geographic area. However, within local areas, the groundwater from sources of the same depth is fairly consistent in mineral quality. Further, the quality of water from a given well can usually be evaluated adequately by a chemical analysis of a single sample of the water. The State Water Survey has made chemical analyses of groundwater samples from wells in Illinois since 1895, and these records provide knowledge of the mineral constituency of groundwater throughout the State.

At the Illinois State Water Survey chemistry laboratories, samples of water from wells, streams, and reservoirs are analyzed to determine their quality

In contrast to groundwater, the quality of the water in a stream varies almost continuously, so that an evaluation must be based upon a series of analyses obtained by a regulated sampling program, rather than upon any single analysis. General quality characteristics of surface water throughout the State now are available.

The quality of surface water sources in Illinois is influenced by location and physiography, and quality differs in the northern, central, and southern regions of the State.

In northern Illinois, where much of the streamflow is from stored groundwater and the amount of flow is more stable, the mineral content of the water also has less variation. The water in streams is harder, largely because of the interchange of water between the ground and the streams.

Continuing southward through the State, changes in physiography lead to progressively greater variability in streamflows, decreasing hardness, and a generally greater variability in mineral composition. Surface waters in the southern parts of the State can also be expected to have slightly higher temperatures than those in the north.

Quality Factors

The mineral quality of water is usually defined by a few key factors that have the greatest effect on general domestic and industrial use. Some important measures for Illinois waters are total dissolved minerals, hardness, iron, and nitrates.

The **total mineral content** includes all the mineral ingredients in the water. High mineralization can make water unsuitable for domestic and industrial purposes. Water with a particularly high mineral content may taste salty or brackish in varying degrees depending on the concentration and kind of minerals in solution.

The Public Health Service Drinking Water Standards recommend that water should not contain more than 500 parts per million (ppm) of total dissolved minerals. Mineralization of more than 1,000 ppm can be faintly tasted. Waters of 3,000 to 4,000 ppm can hardly be called palatable, and at 5,000 to 6,000 ppm livestock do not thrive. At about 18,000 ppm, water is injurious and if used continuously would cause death. Sea water contains about 35,000 ppm dissolved minerals.

In Illinois more than 40 percent of the public groundwater supplies, serving over a million people, exceed 500 ppm total dissolved minerals. No public groundwater supply contains less than 150 ppm minerals. A few towns use waters of 1,500 to 2,000 ppm minerals. Up to about 2,000 ppm, the taste factor may be a matter of custom; in fact, a person used to drinking water of 1,500 ppm minerals would have to become accustomed to 500 ppm water.

Equipment that can demineralize limited quantities of water is available, but the process is too costly for general use. For example, the cost of chemicals to demineralize 100 gallons of water containing 5,000 ppm total dissolved minerals would be about one or two dollars. This would be expensive water for lawn sprinkling, but the water for 16 cups of coffee would cost only one or two cents.

It is appropriate to note here that even sea water can be made suitable for human use, but the methods now known are too costly for large quantities that might serve as regular supplies for cities or industries. Much research is now being conducted seeking more economical methods of desalinizing sea water, since this would be an important means of actually enlarging the usable water resources in many parts of the world. In certain areas of Illinois, there may come a time when desalination of brackish groundwater would be feasible and desirable.

Water is considered '**hard**' when it contains large amounts of magnesium and calcium. But, the distinction between hard and soft water is relative. Persons accustomed to water of 250 ppm hardness consider Lake Michigan water (130 ppm) soft; those used to softened water of 50 to 75 ppm hardness consider Lake Michigan water hard. In turn, anyone who is accustomed to water softened in a home zeolite system (0 to 10 ppm hardness), or to rain water, considers water of 50 to 75 ppm to be hard.

Hard water has a number of effects, very few of them good. Soap and soap products do not clean properly in hard water. The insoluble calcium and magnesium soaps which are formed with hard water leave a film on laundry and a white deposit on dishes.

Hard water causes scale to form in boilers or hot water heaters, because the solubility of calcium carbonate and sulfate salts and magnesium hydroxide is lower at increased temperatures. Such scales increase fuel costs and can create costly maintenance problems. Chemical treatment of water used in industrial boilers that produce steam and power is common and, in most cases, is an economic necessity.

More than 88 percent of the public groundwater supplies in Illinois have a hardness greater than 200 ppm, and in over 26 percent of these the hardness is greater than 400 ppm. About 20 percent of our public groundwater supplies are now treated to reduce hardness to about 100 ppm.

Excessive amounts of **iron** in water also are troublesome, causing stains in laundry and clogging in pipes. The U. S. Public Health Service recommends a limit of 0.3 ppm iron to avoid such problems. Three of every four public groundwater supplies in Illinois have an iron content of more than 0.3 ppm. However, about 38 percent of such supplies are treated for iron removal so that at present 60 percent of the population served by groundwater supplies receive essentially iron-free water.

Excessive **nitrate** concentrations can be a particularly serious problem in water supplies. Such concentrations may be injurious to both humans and livestock. Shallow wells in Illinois are more likely to contain a high nitrate content than deep wells.

Other minerals which can create problems in water supplies are excess chloride, sulfate, and sodium. The sodium content of water, for example, becomes important in preparing salt-free diets. Hydrogen sulfide and methane are gases present in some groundwater supplies in Illinois which can also be troublesome.

Thus, we see that the mineral qualities of Illinois water resources vary and may affect the usability of groundwater and surface water sources. However, in general these qualities are such that they can be removed or treated successfully and economically for most public and private uses. A greater problem is contamination by man, for the waste materials he may add to water can be much more difficult to remove than Nature's mineral and organic substances.

Firefighting — an important use of water

WATER USES AND PROBLEMS

Because Nature made no provision in our body for storing water, we must always live near water to survive, and communities must be located near an adequate source of water to thrive.

Although water's use as a domestic supply may have first priority, it is only one of the multiple uses of this vital natural resource. A stream can support fish, be a source of water for agricultural crops and animals, and a vital natural raw material for the development and very existence of industry, water transportation, and water-related recreation. A stream must often carry away the community's treated domestic and industrial wastes.

The major uses of Illinois water resources are for municipalities, industry and electrical power generation, and agriculture. Much water must be available also for shipping, waste treatment, recreation, and fish and wildlife.

Demands for water for all uses are much greater today than they were even 20 years ago. Part of this increased demand is the result of population growth, but more water also is being used in each home for more numerous water-using appliances. In addition, modern industrial processes require greater amounts of water, as do many businesses.

We have seen earlier that water resources for Illinois are large and are renewed by generally abundant rainfall. But, we have also seen that the distribution of this great water resource is irregular in both time and place. Thus, the usable water supply for any one community has natural limitations in amount and quality.

Problems concerning water then start with supply and demand—having enough water of suitable quality available when and where it is needed. Some other problems affect this basic one. These include problems of land uses that affect erosion, sedimentation, and drainage; droughts and floods; and increased waste loads and pollution. Additional problems concern meeting the water needs of fish and wildlife, and for recreation.

As we look at some of the important uses of Illinois water resources, we shall see some of the related problems and areas of conservation.

Water for Cities

More than 80 percent of Illinois residents live in urban areas, and the water-supply systems that serve them make heavy demands upon water resources.

Municipal water supplies are groundwaters or surface waters, treated as necessary to improve the quality and remove disease-producing organisms, and supplied for general use. The actual uses of this water are myriad—for homes, schools, offices, stores and other businesses, sometimes industries, city cleaning and sanitation, public swimming pools, golf courses, and fire fighting. In each instance, modern use of water is increased by more numerous water-using facilities and appliances, as may be exemplified in dishwashers, automatic washing machines, and lawn sprinklers for home use.

In 1965 municipal water use totaled 1.76 billion gallons per day (bgd), which over the State would average about 200 gallons a day per person. However, this average does not present a true picture because water use per person is much higher in large cities that have a high concentration of business and industry. For Chicago and its suburbs served by the Chicago Water System, the per capita water use is about 286 gallons per day.

In more residential towns and cities in Illinois, water use averages around 100 or 125 gallons per person each day. Domestic water use in rural areas may vary greatly from area to area, but would average about 60 or 70 gallons per capita per day. This is in great contrast to ancient times when each person in a village used 3 to 5 gallons of water per day.

Water–Supply Systems

The first public water supply in Illinois was constructed in 1843 for the City of Chicago, using Lake Michigan as a source of water. The pumping station for this system, which supplied about one-fifth of the 11 square miles of the city, provided about 2 million gallons of water daily. This was the only public water system in Illinois for about 25 years or until 1867 when public water supplies were installed at Springfield and Peoria. Today Illinois has some 1,500 municipal water supplies. In the future we can expect to see water-supply systems established for groups of smaller towns and for rural areas, developing in much the same way as rural electricity.

City water towers take many shapes

The first public water supply in America of which there is any authentic record was installed in Boston in 1652 for the residents of a single neighborhood. The first supply designed to serve an entire community was not installed until a century later at a Pennsylvania village now known as Schaefferstown. Seventeen cities were served by public waterworks by 1800 and 83 by 1850. In 1900 there were 3,300 waterworks, and in 1960 probably around 20,000 municipalities had public water-supply systems.

The initial public water systems in Illinois obtained water from lakes or rivers until 1880 when Rockford installed the first city wells and used the underground supply. These early public water systems were generally privately owned, whereas most but not all now are owned by the municipalities.

Today, although numerous cities and small towns use groundwater, surface waters from lakes, reservoirs, and rivers still serve the majority of urban residents. Lake Michigan alone serves about one-half the population of the State. Some cities (Peoria is one example) draw upon both groundwater and surface sources to maintain adequate supplies for growing populations.

A water supply for a city is very complex. It begins of course with the natural resource of either surface water or groundwater. But the resource must be developed into a water supply, which could mean constructing impoundments or drilling wells. Then, there must be the engineering works that move the water and allow pumping it from the supply source into treatment plants and then storage facilities, and on to the distribution system which carries the water throughout the city delivering it finally into lines that connect directly to homes or business buildings.

No small part of this very complex work is the continuing maintenance of these facilities. The maze of pipe lines that form the distribution system, for example, must be checked for leaks and repaired, old lines must be replaced from time to time, and new lines must be added as a city grows. Actually, the control of leakage in water lines is an important water conservation practice since in a sizeable city millions of gallons of fresh water may be lost in this way.

Water metering is another conservation measure that is being encouraged. In many cases, private residences are not now metered, and the customer is charged a flat rate for water. Individual meters measuring the amount of water used by each customer tend to prevent wastage and allow more efficient management of the total resource.

Water Treatment

Water treatment also is an important part of the water-supply task. Water as it is taken from a natural source, that is, a river or lake or well, is called 'raw' water. Raw water may sometimes be suitable for human use, but ordinarily it must be treated to remove any harmful bacteria or unwanted minerals.

The type of treatment that is necessary for any raw water depends upon the intended use of the water. Treatment of water for drinking or household use, for example, can differ greatly from treatment for use by an industry. A municipal water supply should be clear, clean, safe, and palatable; an industry often can use bacterially unsafe water but may require a very low mineral content.

For the public water supply of one town in Illinois, raw water is pumped from a river into a treatment plant where the solid materials are first removed. Lime and soda ash are next added to soften the water, and activated carbon is added to remove any undesirable color or odor. The water is then allowed to settle before being filtered. Afterwards, it is chlorinated to destroy disease germs; finally, it is pumped into a clean storage reservoir from which it is delivered into the water-supply distribution system.

This one example illustrates that considerable care is taken to assure safe water of good quality for public use. Knowing the many steps involved in operating a public water-supply system, one can better understand that when people pay for water they are paying for a service rather than a product.

Industrial Water Use

Water is used by industry in many ways. It may be an ingredient of a product, such as a beverage, or it may be used in washing a product such as coal. Water is needed by workers in factories for drinking and sanitary purposes. By far the greatest use of water in industry is for the purpose of cooling.

Industries make a heavy demand on our water resource. In 1965 Illinois industries used approximately 14.5 billion gallons per day (bgd). Because of more efficient use and conservation measures, industrial water

Industry makes use of redwood cooling tower where water is used as a cooling agent. Hot water is piped to the top of the tower and spills down through it as big fans (inside the tubs) draw cooling air up through the structure. The cool water then returns to the cooling system through drains at the bottom.

use has remained the same the last few years. However, continuing growth of industry will result in greater demand, even with continued conservation and efficiency.

Cooling water for power generation accounts for 95 percent of the total industrial water use. Fortunately, less than 1 percent of water used for cooling is actually consumed. Most of it is returned to the source unchanged except for a slight temperature rise. Some of it is recirculated, which is a conservation measure.

The 5 percent used for purposes other than cooling becomes an ingredient of a product or is used in processing a product. Major water users in this category are steel industries, mines and quarries, manufacturers, oil refineries, and processors of paper, cement, chemicals, beverages, and food. Only about 4 to 6 percent of the water used in these industries is consumed.

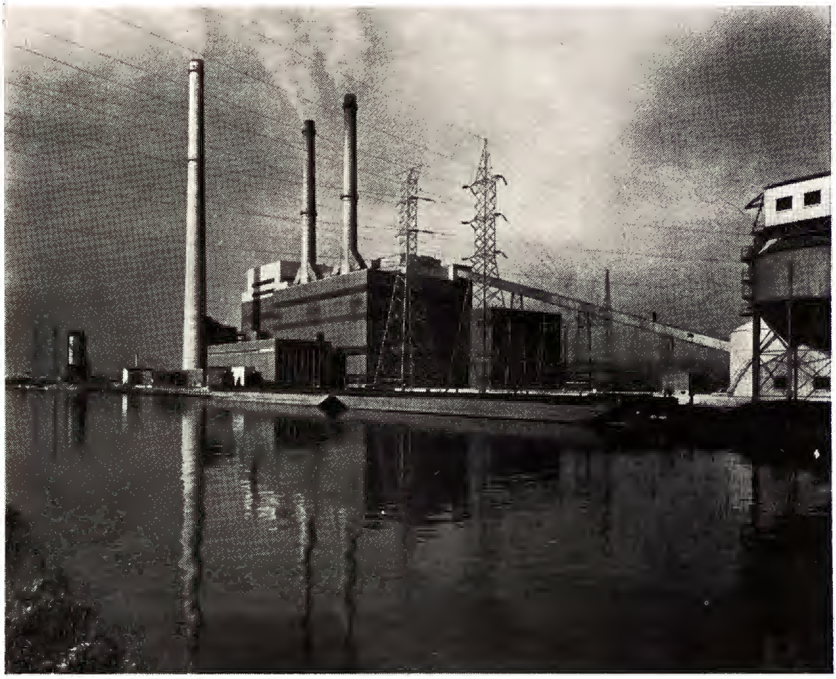
The amount of water required in the production of various products varies greatly. From 7 to 10 gallons of water is required in producing 1 gallon of gasoline. It may take 25 to 35 gallons of water to produce 1 case of No. 2 cans of vegetables. One ton of paper requires about 50,000 gallons of water and a ton of synthetic rubber about 600,000 gallons.

Industries obtain their water supplies by various methods. Some buy directly from a municipal water supply or a private water company. Others locate near lakes or streams and install intakes on these surface sources. Where the groundwater supply is adequate, industries may construct wells on their own property, and in some cases wells have particular advantage to industry because the water may have a consistent and desirable mineral quality and temperature.

By far the greatest part of industrial water, however, comes from surface water sources such as Lake Michigan, the Chicago River and its branches, and the Des Plaines, Fox, Rock, Illinois, Mississippi, Ohio, and Wabash Rivers. Only 0.3 bgd is supplied from groundwater sources, and most of this (0.232 bgd) is from seven counties—St. Clair, Madison, Cook, Tazewell, Peoria, Will, and Winnebago.

Water for Power

At New Salem, visitors to this early home of Abraham Lincoln alongside the Sangamon River can see a reconstructed water wheel that once turned a mill for grinding flour.



Power generating stations require large quantities of water

The water wheel was basic in the lives of pioneers along the American frontier. The energy of flowing or falling water has been used since ancient time and continues to be important in many parts of the world today. The design of a water wheel is simple, with vanes or buckets attached to the periphery of the large wooden wheel. When water is applied at the top of the wheel, the buckets fill, or the vanes are forced downward, turning the wheel by gravity in the direction of the flow of water. If water enters the wheel at the bottom, the force of the flow turns the wheel in the opposite direction.

The turbine is a modern type of water wheel which is widely used today as a source of power, particularly for the generation of electricity. The turbine transmits the pressure of a stream of water into mechanical energy sufficient to drive electric generators.

Because of predominantly flat terrain, Illinois has few locations suitable for constructing hydroelectric plants. There are 10 operating hydroelectric plants in the State which produce less than 4 percent of our total electric power.

The greatest amount of electric power for Illinois is produced by steam-generating plants, which must be located near a large supply of water for cooling and condensing. Illinois has more than 80 generating and distributing systems, which may be public systems, cooperatives, or private investments. The larger installations, mainly in northeastern Illinois where most of the electric power is expended, are located on the Chicago Sanitary and Ship Canal, the Illinois River, Lake Michigan, the Mississippi River, and the Rock River. Three new plants using reservoir resources are near Marion, at Kincaid, and at Coffeen in south-central Illinois.

In hydroelectric plants water is not consumed but merely passes through the turbines and returns to its source, or is recycled back into the operation. Steam-generating electric power plants likewise employ water but consume little of it. It is returned to the original source with only a slight increase in temperature.

However, the necessity for immense quantities of water in producing electrical power presents a problem for the future when more large plants are needed. Since suitable water bodies are limited in Illinois, power plants will need to reuse water extensively and are seeking new and more efficient generating methods that do not require such large water supplies.

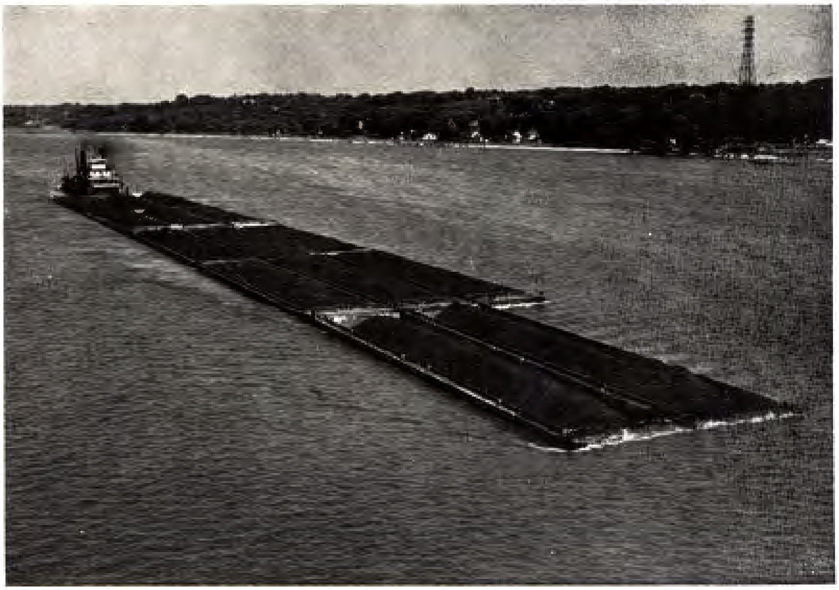
Transport by Water

Natural waterways are an important factor in the development of an area. Early settlers traveled along the Cumberland, the Ohio, the Missouri, and the Platte, traversing almost the width of the United States by water. The long St. Lawrence-Great Lakes-Mississippi system helped open interior North America.

Fortunate in the number of its streams, Illinois might be called a state of rivers. Within its boundary lines, the Illinois River is the only commercially navigable river today; however, bordering the State are the Mississippi River, the Ohio River, and Lake Michigan which are not only navigable, but connect Illinois with the Gulf of Mexico and the Atlantic Ocean.

During the settlement of America, a need was felt to supplement and connect the natural waterways by means of canals, many of which continue in use today. The possibility of connecting the Illinois River and Lake Michigan by a canal was noted as early as 1673 by Joliet and Marquette.

The Erie Canal, which had been opened in 1825, along with the Great Lakes and then the Illinois and Michigan Canal completed in



Barge transports coal on Mississippi River

1847, formed a vastly improved route of immigration from the Atlantic seaboard to the Midwest. The tide of immigration swung from the Ohio valley to the north with settlers entering Illinois at Chicago.

In early days, it was possible to cross most of upper Illinois by canal from Lake Michigan to the Mississippi River by means of the Illinois and Michigan and the Illinois and Mississippi Canals. The eastern terminus of the Illinois and Michigan Canal was at the South Branch of the Chicago River at Ashland Avenue in Chicago, and the canal continues 96 miles west to the Illinois River at La Salle-Peru. As constructed, the canal was 60 feet wide at the top water line, 36 feet wide at the bottom, and 6 feet deep. Its small size soon limited its usefulness.

The Illinois and Mississippi Canal has a right-of-way width of 300 feet. Crossing the State for approximately 40 miles, it connected the Illinois and Mississippi Rivers from about 12 miles west of La Salle to the Rock River near Colona. These canals are maintained largely for historical interest, but the Illinois and Mississippi Canal is now being considered for much-needed recreational development.

Two other canals used to a great extent and extremely important to commercial navigation are the Calumet-Sag Channel and the Sanitary and Ship Canal, both in the Chicago area and considered part of the

Illinois Waterway. The present Illinois Waterway provides through-navigation from the Mississippi River near Alton to Lake Michigan with a minimum channel depth of 9 feet.

The waterways and ports of Illinois have an important and permanent role in the State's transportation system. The Mississippi and Ohio Rivers, the Illinois Waterway, and the St. Lawrence Seaway form an extensive inland system for commercial navigation.

Since the Seaway was opened in 1959, the Port of Chicago has become an important world export center. Grain, processed animal and vegetable products, and manufactured goods enter the foreign market from Chicago. New iron ore deposits in Labrador were made accessible to the Chicago steel industry by the Seaway.

Coal travels the Mississippi and Illinois system to fuel Chicago power plants; grain is shipped by barge to New Orleans or Chicago; petroleum is shipped from refineries to Illinois distributing centers.

Waterway improvement projects are being studied for the Illinois system, the Illinois-Mississippi Canal, the Big Muddy and Saline Rivers, and the Wabash. A navigation project on the Kaskaskia River is underway.

The increasing demand for water-related recreation has prompted proposals for recreational development of Illinois waterways. Most of the proposals are for development of Illinois' major rivers or conversion of abandoned commercial waterways for recreational use. The Fox River canalization project is probably the only new recreational waterway under construction in the United States.

Agriculture, Land, and Water

Water for Agriculture

More water is used for agriculture than for all other uses combined when we consider the water used from the soil moisture reservoir for growth of vegetation. This use has first call on all precipitation, the basic source of our usable water resource.

As we saw in the hydrologic cycle, the transpiration from growing plants consumes about 33 billion gallons per day from our annual total precipitation that averages 100 billion gallons per day. This is considered a consumptive use of water, since the moisture transpired from plants goes directly back to the atmosphere as a vapor and is not available for immediate reuse for man's needs.

The use of soil moisture by vegetation is a natural, highly beneficial, and practical use of this part of our water resource. Actually water caught in the soil cannot be otherwise used directly, and as we shall see later, vegetation (aside from its all-important food function) is extremely important in the land-water conservation cycle. If there were no vegetation, rainwater would run off the land surface in great sheets, eroding the soil and filling streams with sediment, and there would not be time for adequate seepage to replenish groundwater.

In a humid climate such as Illinois, Nature normally provides more than ample precipitation for vegetation as well as other needs. Indeed, generous rainfall combined with flat terrain and deep glacial soils that hold much water make drainage a major problem for agriculture in Illinois. It is only during occasional drought periods in the growing season that growing crops use up available soil moisture before it can be replenished, and require added water from irrigation for normal growth and yields or, in extreme cases, for survival.

Other agricultural water uses include water for domestic use, for watering livestock and poultry, and for spraying fruit trees. These needs are supplied from wells, streams, and farm ponds. Altogether, these uses amounted to about 113.5 million gallons per day in 1965. This does not include water used for supplemental irrigation.

Amounts for specific uses vary widely. Farm homes may use from 20 to 100 gallons per person per day, depending on plumbing and appliances. Poultry take about 6/10ths of a gallon each per day but cattle require around 35 gallons a day per head. Spray solutions used in a year on apple and peach trees in Illinois contain over 13 million gallons of water.

Land Use and Water

Land and water are interlocking resources. The quantity and quality of our water resource are closely tied to the condition and use of the land resource. Abuses of the land create problems in both surface waters and groundwater.

The usefulness of surface supplies greatly depends on watershed protection against sedimentation and contamination. Watersheds must be protected from erosion and managed so that they will provide a maximum of clear water with a minimum of sediment.

Erosion and Sedimentation. When rain falls on tilled land, it loosens tiny soil particles which are carried in suspension into drainage channels and then into streams and finally into lakes and reservoirs or into

Severe erosion on unprotected hillside

the oceans where they are deposited. Eventually sediment can choke a stream or, in the case of a reservoir, entirely replace the storage space intended for water.

Each year approximately 543 million tons of sediment washes down the Mississippi River and into the Gulf of Mexico. This amount of sediment is equivalent to the top 7 inches of soil from ten 160-acre farms washing away each day. In weight, it is great enough to cause the earth's crust to buckle. Part of this sediment in the Mississippi River comes from Illinois.

Millions of dollars is spent each year for dredging our streams and lakes or treating water to remove soil particles so that it will be usable. The loss in valuable top soil that sedimentation represents is incalculable.

An example of misuse of soil and water causing erosion and sedimentation damage in Illinois occurred on the Galena River. In the early 1800's the river, which was 12 to 16 feet deep and 300 feet wide, made the city of Galena a thriving port. By 1880 the river channel was too narrow for navigation without constant dredging. Half the river channel was silted completely by 1910. As the channel narrowed, damage from floods increased, and today this flood damage amounts to about $70,000 annually.

Worse than the loss of the navigable river or the costly flood damage is the loss of the vast amount of fertile topsoil. It eroded from the farm hillsides and is gone forever, leaving gullies from 2 to 14 feet in the ridgelands and field gullies as deep as 3 feet in the cropland. It is estimated that the Galena River basin has lost half of its original 10-inch topsoil to erosion.

Lake Sedimentation. Another dramatic story of the serious effects of sedimentation in Illinois concerns Lake Decatur on the Sangamon River in Macon County. When constructed in 1922, Lake Decatur had a surface area of 2,805 acres and a storage capacity of 19,738 acre-feet. By 1966, the amount of sediment deposited in Lake Decatur had reduced the water surface by 201 acres and the volume of water by 6,973 acre-feet.

Deposited sediment takes space intended for water storage

It was estimated that between 1922 and 1966, more than 9.2 million tons of soil was deposited in the lake or passed over the spillway, an amount equivalent to removal of 7 inches of fertile black prairie topsoil from 9,150 acres. When one considers that, on the average, 3,500 years would be required to form 7 inches of soil and that this amount of land was lost from the Lake Decatur watershed in a mere 44 years, one begins to realize the seriousness of the problem.

Yearly sedimentation in Lake Decatur has begun to decline. In 1966 sedimentation was 0.24 tons per acre per year contrasted with 0.30 tons per acre per year in 1936. It is felt that soil conservation practices begun on the watershed partially account for this reduction. Studies throughout the United States have shown that such conservation programs can effectively reduce sedimentation.

Conservation. Planting trees and grasses, sodding natural waterways, and contour farming are several of many conservation measures which help protect soil and water.

Whether they know it or not, people in all segments of the population are concerned with conservation on the land. Soil and water conservation is not for farmers alone.

The agricultural soil and water conservation program of the U. S. Soil Conservation Service is based on soil surveys. These give erosion and slope information, as well as knowledge of the soil types on individual farms, which is essential for development of sound farm conservation plans. A soil map then provides the basis for a land-capability map, which delineates areas suitable for crop cultivation without special problems, areas of caution suitable for only selected crops, and the danger areas usually requiring protective plantings.

Recently, urban planners have come to recognize the value of using soil surveys and land-capability maps in assigning land uses for urban development. Such maps can be interpreted to show the soils that are good sites for roads, private dwellings, schools, septic fields, commercial areas, parks, and other urban facilities. At the same time, it shows soils that are not suitable. The soils unsuited for homes, schools, or other buildings may be fine as sites for parks, golf courses, wildlife sanctuaries, or agricultural crops. Attention to the appropriate land use in urban areas could help to avoid serious soil and water problems such as flooding of streets and basements, corrosion of utility pipes, poorly functioning septic tanks, and foundation failures.

Owners and users of agricultural land, with the aid of professional conservationists and others, have already made considerable progress in applying conservation practices in Illinois. However, erosion is still a major problem requiring conservation treatment on cropland. Other important problems are excess water and some unfavorable soil conditions. Altogether, some two-thirds of the Illinois' cropland still needs soil and water conservation treatment of some kind. In addition, much pasture and woodland needs conservation treatment, improvement, or protection.

Technological advances are expected to help meet the food and fiber needs of large future populations, but the soil and water resources on which to practice the modern methods and use the new machines and chemicals must be preserved. Many and continuing land use adjustments will be needed for both regions and individual farms.

The increasing use of land for nonagricultural purposes involves more and more people with first-hand conservation responsibilities. The developer of suburban housing, the builder of an industrial plant, the proprietor of a golf course—in fact, every householder, whether in city, suburb, or country—is concerned with the soils and hydrology of his particular site. Each is a land user in his own right and shares with the farmers and ranchers of the Nation the need and the responsibility to practice conservation. So, as land resources are increasingly divided among many uses, the conservation job is more widely spread through the entire population.

Drought and Irrigation

Just as land use affects water so does water or the lack of it affect land use. Drought is a major example of this interdependence. Drought, which occurs when rainfall is lacking or deficient for some time, is hard to define. A dry period of a few days or weeks may affect agriculture, but usually only much longer periods, several months or years, affect water supplies.

Shoreline recedes from boat dock in reservoir during severe drought

Drought Variations. Drought or dry periods in Illinois vary greatly in their time of occurrence and duration, in severity (or departure from normal rainfall), and in geographic location. Droughts do not occur in cycles in Illinois. One of the most severe drought periods was 1930 through 1936, when many dry periods occurred over varying but extensive areas of the State. More recent notable droughts were in 1953-1955 and in 1962-1964.

In general, precipitation droughts in Illinois are most frequent and most severe in southern and southwestern Illinois and are least frequent and least severe in northern and eastern Illinois.

Meteorological studies of Illinois droughts show that the basic weather condition lacking during severe droughts is strong convection. This means that there are fewer days of heavy rain, fewer thunderstorms, and fewer convective clouds. Such conditions occur when there is a blocking continental high pressure system in southern Canada that prevents major storm systems from moving across Illinois. Scientists have found that it is because of this lack of proper clouds and the lack of unstable conditions by which they might form that cloud-seeding to artificially induce rainfall is not successful during actual drought periods.

As we have already noted, the basic water resource for agriculture in Illinois is the moisture in the soil, which is directly related to rainfall. In general, if rainfall is deficient, soil moisture is deficient. However, the extent of the problem may vary because the kind of soil and the kind of vegetation on it affect the amount of moisture retained in the soil.

Because of the great variability of our rainfall from month to month and year to year, droughts can affect agriculture and become a major problem in southern Illinois where the variability is greater.

Agricultural drought begins when vegetation can no longer obtain water from the soil to replace the amount being transpired into the atmosphere. Therefore, information about soil moisture conditions must be available so that water can be supplied before vegetation wilts. Thus, agricultural drought needs to be considered in terms of the water budget for the particular area and crop requirements. As calculated on a monthly basis, the water budget shows the amount of moisture lacking in the area.

Irrigation and Its Problems. The use of irrigation to combat short-term agricultural drought is increasing even in Illinois, a humid state.

Only 307 acres were being irrigated in 1940, but irrigation had increased to about 1,500 acres in 1950, and to more than 14,000 acres in 1964. The amount in any one year has reflected weather conditions, with sharp increases in dry seasons. Irrigation of our major crops, corn and soybeans, has increased notably in recent years. Earlier, truck crops

Irrigation is used to increase crop yields in dry seasons

and flowers accounted for most of the irrigated acreage in the State. At this time widespread use of irrigation in Illinois is limited by economic benefits. Since irrigation is very expensive, other means of increasing crop yields are tried first.

A method for estimating the amount of water required to bring about a maximum crop yield in any season and any location in Illinois has now been devised by Water Survey scientists. From this can be calculated the amount of irrigation water that might be needed to supplement precipitation during the various growing seasons that occur in Illinois.

Irrigation, particularly in arid and semiarid regions of this country, involves tremendous amounts of water, and for the Nation as a whole is the largest single consumptive use of water. Irrigation is considered to consume water since much of it evaporates, sometimes even before it reaches the crops that need to be watered, and is therefore lost for our immediate reuse.

Concomitant with irrigation are several problems related to water and soil quality. In some areas vast amounts of groundwater are pumped for irrigation to the point that the soil beneath becomes compacted, causing the ground surface to subside as much as 20 feet in places. Along some coastal areas, salt water, which is not usable, has crept in where fresh water has been withdrawn for irrigation. Still another problem has been the leaching of minerals into soils from irrigation water which has become mineralized from repeated use. This leaching causes the ground to become alkaline and unsuited for crop production.

Research for the Future. Current scientific research on retarding evapotranspiration (the combination of surface evaporation and plant transpiration) may someday provide another solution to soil moisture problems during drought periods, a solution that does not strain valuable fresh water resources as irrigation does.

In laboratory and field experiments, fatty alcohols that retard moisture loss are applied to the soil. This lessens the moisture used in evapotranspiration. In effect, plants would use only the moisture they need for growth, and the rest would be preserved in the soil, thus being available for the plants to use during dry periods. In some tests, corn plants in treated soil have been grown with 20 to 40 percent less water than plants in untreated soil. Other studies are being made of the use of similar fatty alcohols to form a monomolecular film on water surfaces, which retards evaporation and thereby conserves the water in farm ponds and reservoirs.

Much more research will be needed before such possible methods may be of practical use, but scientists see their development as important in meeting increased total demands for water in the future.

Floods and Their Control

Floods and flooding cause extensive and costly destruction throughout Illinois. Few areas in the State are totally safe from the inundation caused by the overflow or ponding of excess precipitation runoff. More than 4 million acres of bottom lands in Illinois are subject to flooding, about 11 percent of the land area of the State. This percentage of flood-prone lands is twice the national percentage, which is about 5 percent.

Although Illinois has had a number of widespread and devastating floods on its major streams, the greater part of the annual flood damage is the sum of numerous floods on small streams.

Floods in Illinois. The greatest floods of record were those of 1943 on the Illinois River and its tributaries and the Mississippi River flood of 1965. A major disaster, the 1965 Mississippi River flood created havoc from Minnesota to St. Louis and caused approximately $25 million in urban and agricultural losses in Illinois alone.

Floods can destroy land, property, and lives

However, most flooding in Illinois occurs on the smaller rivers and streams with relatively lower damage costs. As one example, the December 1965 flood on the Calumet-Union Drainage Ditch, a minor stream in southern Cook County, resulted in damages of $263,723 to 326 homes. It is the cumulative losses from these much more frequent but less publicized floods that cause the average annual flood damages of $30 million in Illinois.

Flood-producing storms may occur at any time in Illinois, but the frequency is greatest from late spring to early fall. Winter storms are restricted mostly to the southern part of the State. Basically, flood-producing storms are of two types: the cold-season storms over a large area, which frequently produce copious rainfall for two to five days; and the warm-season storms of mid-April to mid-October in which most of the rainfall occurs in less than 24 hours and is much more intense at the storm center. These excessive rainstorms of late spring to early fall may cover a few square miles or thousands of square miles, depending on the current (synoptic) weather conditions with which they are associated. Historically, the most severe rainstorms have occurred in the south-central section of the State.

Controlling Floods. There are various methods of flood control. These include structural measures such as reservoirs, channel improvements, levees, and by-pass channels, or a combination of these. Regulatory measures such as zoning, building codes, or construction limits are also effective means to flood control.

Detention reservoirs, the most familiar flood control structures, reduce the quantity of discharge during flood periods by storing the water in an upstream area for controlled release when downstream flows subside. A detention reservoir may be either single- or multi-purpose in design. The single-purpose reservoir is often used for control of headwaters for agricultural protection. The multi-purpose reservoir is used on larger streams or near centers of population where it can also be managed for water supply, recreation, or other purposes. Operation of either type of reservoir requires that space allocated to flood storage be emptied of water as soon as possible after a flood, in anticipation of the next period of excess flow.

Multi-purpose reservoirs are often regulated to keep rather high and stable water levels in summer for recreation and conservation needs, but the water levels are then lowered in winter to be ready for heavy spring rains. Use of a detention reservoir for flood control reduces downstream discharges and makes other control measures less costly.

Among other structural measures to reduce flooding, channel improvements have been common in Illinois, particularly in urban or other areas not suited for reservoirs. Channels are improved by cleaning, straightening, or deepening, so that more water can move more rapidly through them without overflowing. Many levees also have been constructed in Illinois to contain flood waters within restricted channels or floodways, particularly to protect agricultural lands. Flood walls serve a similar purpose to protect buildings near waterways in urban areas.

Regulatory measures help reduce flood damage by preserving the floodplain lands to accommodate flood waters. This approach requires local zoning ordinances, subdivision regulations, building codes, encroachment limits (areas where no construction is permitted), and other controls on the use and development of property on the floodplain.

Flood forecasting of impending high flows, temporary evacuation of floodplain lands, warning signs posted on flood-prone properties, and flood-proofing of existing structures are supplementary measures that help to lessen damages during flood periods. At present, forecasting of floods on the larger rivers and streams of Illinois is usually effective and valuable. Unfortunately, it is extremely limited on the smaller watersheds where the time lapse between precipitation runoff and peak flow is quite brief.

Problems of Control. Considerable effort and millions of dollars have been spent throughout Illinois for the prevention or control of floods. The flood control program has not been entirely successful, primarily because of man's increasing invasion or encroachment on natural floodplain lands.

The shift from an agriculturally oriented society to a highly urbanized and industrialized society has been the principal cause of encroachment on the floodplains. This change in the social and economic structure has been in progress for more than half a century. In general, the population has increasingly concentrated in and around centers of industry and business and has pushed further and further out from the urban core onto agricultural lands.

In recent years a growing population, an affluent society, and better roads and other transportation have resulted in a great expansion of residential and light industrial development into the countryside. These have reached out into the floodplains of the smaller streams of the State.

When used for agriculture, these lands were subject to occasional and often frequent periods of inundation lasting from one to several days. The farmer, with his knowledge of the soil, terrain, and crops, expected and planned for these flood periods. As a result, his farm normally suffered only minor damages. As urban encroachment occurred, with its many kinds of development, the flood that formerly inflicted only small damages now created a catastrophe resulting in thousands of dollars in losses.

Urban encroachment on the floodplains not only has greatly increased local flood damage losses, but also has aggravated flooding conditions on downstream waterways. Properties and communities which never had been extensively flooded now suffer increasingly severe flood damages. Urbanization restricts both the channel and the floodplain and thus obstructs the natural flow and spread of flood waters and causes increased flood stages upstream.

In urban areas buildings, roads, sidewalks, parking lots, and storm sewer systems take over areas of pervious soils or natural depressions that hold water. The result is a decrease in natural local seepage and storage and an increase in runoff from precipitation. Thus, even for a relatively mild storm, the percent and rate of runoff are increased, requiring larger channel capacities downstream than would have been required had the area remained in its natural state.

Urban parking lots and buildings change normal seepage and drainage patterns

The only practical solution to these flood problems lies in the comprehensive watershed study. In this way a particular flood control measure, or a combination of several measures, can be used to eliminate the negative influence of an upstream improvement on a downstream problem area. Through comprehensive watershed studies due consideration can also be given to the use of flood control measures, such as detention reservoirs, to meet the other needs and uses of water.

Water for Recreation

Enthusiasm for water-related recreation has been growing at a tremendous rate in Illinois and throughout the Nation. There is an increasing interest in water sports and outdoor activities such as swimming, boating, water skiing, wildlife hunting, and fishing. We also seek lakes and streams in connection with pleasure driving, sightseeing, picnicking, and camping.

All of these activities are in growing demand for several reasons. A principal one is that more and more people live and work in crowded urban areas and therefore seek uncrowded land and water areas in their leisure time. In addition, the shorter work week and longer vacations in our present society provide more leisure time, while automobiles and transportation improvements give us greater individual mobility.

Our facilities for water-related recreation are inadequate today, but we have many possibilities, especially in our river valleys, for developing outstanding recreational centers.

One of our urgent water problems is to preserve and develop these resources now to meet our growing outdoor needs in the future. If this is not done, the resources may soon be lost through city growth, pollution, or incompatible land and water uses. Governmental agencies are working on programs that would ensure recreational developments in coordination with other uses of our surface water resources.

Part of our recreation problem stems from the fact that Illinois has fewer acres of public open-space in relation to its population than any other state in the Nation. At this time over 94 percent of the land area and 85 percent of the water area of the State are in private ownership and thus not open to the public. Public open-space is only 565,178 acres or 5.7 acres per 1,000 population. To add to the problem, nearly half of this space is in extreme southern Illinois, far removed from the Chicago region where 62 percent of the people live. Recreational needs and space problems are greatest near all urban centers in Illinois.

Water Activities and Resources

Swimming is the top ranking water-related recreation in the Nation today. It is relatively inexpensive and can be enjoyed by all age groups. Except for a few private and municipal beaches, most Illinois residents have had to depend on urban pools for swimming. Illinois Beach State Park on Lake Michigan is the only public beach in the entire State Park system.

The problem of keeping water pure enough for swimming has been the main deterrent to beaches in parks or other natural swimming facilities in lakes and streams. Recreationists hope to enlarge swimming opportunities in Illinois through sanitary control measures. For example, new city water-supply reservoirs through the State and the seven new Corps of Engineers multi-purpose reservoirs could provide extensive swimming possibilities if water-quality needs are properly considered. Quality is actually of greater concern for swimming and other body-contact water activities than for water supplies because water for drinking is processed through treatment plants before being used.

Swimming, a favorite recreation for all ages

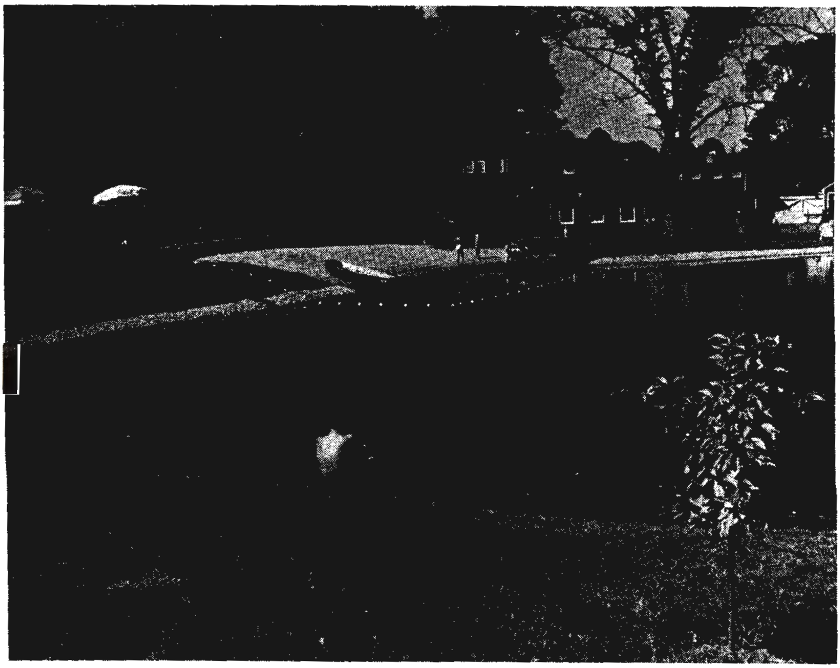
Pleasure boating has grown to be a leading form of recreation in Illinois. More than 150,000 boats were registered in 1964, an estimated 200 percent increase over registrations in 1950. Greatest increase has been in smaller powerboats, although canoes and sailboats also have grown in popularity. Illinois was the first State to enact a zoning law for the use of public waters, which fortunately now eliminates conflicts between different kinds of boats, such as speedboats and sailboats, and protects the interests of fishermen, water skiers, and swimmers as well.

Illinois has approximately 2,800 miles of rivers and 138,317 acres in interior lakes or reservoirs of at least 40 acres which are suited for smaller powerboats. The new Corps of Engineers multi-purpose reservoirs will add some 80,000 additional acres. Sailing waters exist on the larger pools on major rivers such as Peoria Lake, and on some city water-supply impoundments. More than 3,000 miles of streams in the State are suitable for canoeing, principally the Fox, Apple, Rock, Illinois, Sangamon, Embarras, and Kaskaskia Rivers. In addition, the great Mississippi River system can be explored by touring boaters, and our 63-mile Lake Michigan shoreline is available for owners of larger craft.

Increased popularity of boating has caused many of the favored boating waters to become overcrowded. In addition to more water space for boating, better access to water and boat service centers are needed.

Although interest in fishing has leveled off in recent years, sport as well as commercial fishing is still big business. In some cases poor water quality and pollution have degraded the quality of fish and made sport fishing less desirable.

Illinois has 2,068 impoundments of over six acres for a total water surface of 152,143 acres, and fishable rivers and streams total 9,351 miles. However, a recent study shows that 96 percent of these impoundments and 85 percent of the streams are privately owned and controlled. Public fishing waters are especially lacking near urban centers. The thousands of farm ponds in Illinois have provided family fishing opportunities, and an increasing number of farm owners are developing small fishing-lake resorts which supplement farm incomes and open up local fishing possibilities.



Attractive suburban pond provides recreation, or an emergency supply of water

Efforts are now being made by several state and local agencies to clear up pollution in certain streams, to acquire easements for public use of some waters, to develop public conservation lakes, and to encourage scientifically managed fishery programs.

Waterfowl Hunting

Illinois is one of the top waterfowl hunting areas in the Nation, but the State's resources are limited despite its location as a key state in the patterns of waterfowl migration. Several migration routes from Canada merge over Illinois into the single concentrated route of the Mississippi Flyway. The Illinois River valley, located in this migration path, has particularly good recreational potential for waterfowl hunting.

Illinois now has only 80,000 acres in prime waterfowl lands and 200,000 acres of secondary wetlands. This has come about primarily because thousands of acres of riverside lakes and marshes have been leveed and drained. The Illinois Department of Conservation presently controls more than 43,000 acres of waterfowl area. Because of increasing demands for land, the amount of waterfowl habitat may be further decreased, as portions of suitable lands are converted to private use or changed to meet other recreational demands.

Although providing opportunity for hunting is a basic objective of waterfowl preservation, other interests are equally concerned. In 1962, less than 4 percent of the visitors at National Wildlife Refuges were hunters, which indicates the interest of bird watchers, wildlife enthusiasts, pleasure photographers, and sightseers in wildlife preservation.

Both state and federal agencies are taking steps to preserve waterfowl and waterfowl habitat in order to stop the steady decrease in waterfowl populations. To the traditional natural threats of disease and weather have been added the man-made threats of insecticides, water pollution, and destruction of resting and feeding places. The programs for preservation of waterfowl and of waterfowl hunting as a recreational activity will require the interest and support of the public.

Water Pollution

Water pollution is a serious and ever-growing threat to the usefulness of our water resources. It is a matter of great national and international as well as state and local concern, a problem bearing a price tag of billions of dollars.

But, what is water pollution? Where does it come from? How can it be managed or controlled? Let us look briefly at the answers to these questions, for solving the problems of pollution is an important part of water conservation.

Pollution is very hard to define, for it has many degrees and variations. We need to consider once again the natural properties of water—its ability to pick up, carry, and dissolve other substances. Even a raindrop may pick up a particle of dust in the air and be impure before it falls, or a clear mountain stream untouched by man may pick up and carry soil, minerals, even bacteria from the earth over which it flows.

Since water accepts almost anything and everything it comes in contact with, it always contains impurities—of many kinds. These foreign substances may alter some original quality characteristic of the water; here, however, we must remember from our study of water quality that no one quality suits all purposes. It is when alterations become harmful to legitimate water uses for domestic, industrial, agricultural, and recreational purposes, or to fish and wildlife, that we consider it to be pollution.

There are of course many degrees of 'harmfulness' or pollution, and these will vary with the intended use of the water. For example, the preferred limit of total minerals in drinking water is 500 parts per million, and totals of 1,500 to 2,000 ppm are used without trouble; however, less than 1 ppm can be allowed in the feedwater for an ultramodern steam power plant. Further, water in a stream must contain dissolved oxygen for the growth of fish and aquatic life, but water containing dissolved oxygen is corrosive to all metals.

The explorers and pioneers moved into Illinois by way of its rivers, and they built settlements along the banks of rivers for both water transportation and water supply. They also used these rivers as an outlet for their waste products. This was no problem. There was plenty of water to serve all of their purposes.

Then the settlements grew into towns and cities, became more numerous and closer together, and industry developed. Waste products also multiplied and changed in form and complexity. Epidemics of typhoid and other waterborne disease occurred, fish were killed, and wildlife disappeared. So, the use of rivers and streams to carry wastes became a problem—and is an increasing one in our modern complex society.

Waste loads too great for the rivers cause pollution, harming the use of the water for all water-supply needs, often greatly increasing the cost of treating drinking water, and frequently causing the water to be unusable for fish, wildlife, and recreation. In addition, pollution

Dumped trash pollutes streams and makes streambanks unsightly

causes our waterways to be unsightly and to have sickening odors. Still, however, the transport and dilution of waste is an important, natural, and necessary use of water.

Natural Purification

Nature gave flowing water a remarkable ability to absorb wastes, convert them into useful or harmless substances, and thereby cleanse itself. A stream then is a natural and usually highly efficient sewage treatment plant; as in most of Nature's processes, however, efficiency depends on prescribed limits and balances.

Self-purification of a stream is accomplished by both mechanical and biochemical operations. Movement of the water breaks up some larger solids into fine particles that settle to the bottom or are diluted and thus made harmless. Dissolved oxygen in the water oxidizes some organic wastes, that is, burns them chemically, and oxygen also acts indirectly, supporting harmless bacteria and microorganisms that feed on sewage. The oxygen in water comes both from the air and from water plants which give off oxygen during the process of photosynthesis.

If an overload of wastes is poured in the stream, the supply of dissolved oxygen runs out before the wastes are digested, and purification stops until more oxygen is acquired. If overloads are continued at one location or if successive loads are added by downstream communities, the stream may never catch up.

A stream's capacity to purify itself depends on its physical characteristics such as its size, depth, velocity, slope, and the variable amount of runoff reaching it, as well as on its chemical and biological makeup.

Obviously, small streams have less waste-assimilation, or self-purification capacity, than large rivers, and this capacity can easily be exceeded during periods of warm weather and low flow. This is of increasing concern in Illinois, where waste loads have increased on relatively small streams in the prairies as the result of expanding towns and industry and agricultural changes.

Sanitary Systems and Treatment

As towns and cities grew, our citizens soon realized that streams could not do the waste-disposal job alone. Thus, sanitary sewer systems and sewage treatment plants were developed to protect public health.

In another section we mentioned the very complex municipal water-supply system. Equally complex for our cities is the sanitary system that carries used water and wastes away from our homes and business buildings. From the home the water drains through waste pipes into sewer mains, through which it flows to the sewage treatment plant or directly to a point of discharge into a flowing stream.

The sewage treatment plant utilizes much the same principles as the river in transforming wastes into harmless substances and purifying the water so that it can be used again. Municipal or domestic raw sewage is 99.9 percent water; the rest is solid or liquid wastes from homes and businesses, primarily organic material.

In the treatment plant solids are first screened and settled out of the waste water; then bacteria that feed on sewage solids are added and the mixture is agitated or aerated to increase the dissolved oxygen and thereby speed the digestive process. The water again is allowed to settle before being discharged as clear water. Even this clear effluent (outflow) from a sewage plant must be disinfected with chlorine or some other chemical before it is safe to drink. The solids that were removed in the plant are generally acted upon by bacteria in the absence of oxygen, in temperature-controlled tanks or digesters, converting a portion of the organic matter to odorless gases which may be used as fuels. The solids remaining after digestion also must be disposed of and in some cases may be dried and used as fertilizer or fill.

There are several methods and degrees of waste treatment. Varying procedures may be used so that an increasingly greater percentage of oxygen-consuming organic materials, solids, and perhaps specifically undesired inorganic materials can be removed. Treating industrial wastes may require special filters that can exchange, for example, a toxic metallic waste for a harmless substance.

Such advancing degrees of waste treatment add progressively to the cost. If the receiving stream is to be used for swimming or water-skiing, for example, additional treatment and disinfection is required, which is more expensive. Greater degrees of waste treatment are needed when the receiving stream carries a waste load near or beyond its self-purification capacity.

More than 80 percent of Illinois residents live in areas served by complete sewer systems and sewage treatment works. A few hundred small towns in Illinois, most with less than 500 population, do not have sewer systems, but as small towns grow they find it necessary to install such systems to protect health and correct local nuisances. Some residential developments in rural areas and farm homes depend upon septic tanks for waste disposal, but these are sometimes inefficient or unsatisfactory, and great care must be taken to avoid contamination of soils and groundwater sources.

In conserving the quality of our water resources, one of our greatest needs is adequate treatment of industrial and municipal wastes before they are discharged into streams. Methods for generally adequate treatment are now known: the problem lies in financing and building new or expanded sewer systems and treatment facilities fast enough to keep up with the rapid growth of cities and industries.

Sources and Indicators of Pollution

Although pollution may come from almost any source, we are most concerned with pollutants from municipal, industrial, and agricultural wastes. Pollutants in municipal wastes are primarily human wastes, and although we have seen that natural or common treatment processes take care of these easily, it is important that adequate treatment exist to assure destruction of pathogenic or disease-producing organisms which are always potentially present.

Industrial wastes are myriad. They include toxic metals and chemicals, solids carried in suspension, salt brines, acids and alkalies, oils, and dyes. Some of these may be a special problem in that they are not easily decomposed by conventional sewage treatment, and some interfere with treatment for organic wastes. Consequently, many industries must pretreat their wastes before they discharge them into municipal sewerage systems. Large industries or those that have special problems may have their own treatment facilities.

Silt from soil erosion, resulting from poor land use, accounts for a large proportion of agricultural pollution. Removal of silt is a costly problem in treating drinking water supplies. Spills of pesticides and the washing of spray equipment in streams may contribute direct pollution to streams. Careless or excessive application of fertilizer containing phosphates or nitrates is another source of contamination. Fertilizer from fields as well as wastes from livestock and poultry feeding areas sometimes are carried unexpectedly to nearby streams during heavy rains.

Nutrients such as phosphates and nitrates, which come from detergents and other domestic and industrial wastes as well as from agricultural sources, are needed in the normal cycle of aquatic life, but an over-richness promotes massive growths of algae and plankton which deplete oxygen and disturb the normal cycle. Algae and plankton growths may be troublesome to water-supply plant operation and cause taste and odor problems.

Bottom-sampling device is lowered into river to collect samples for research on improving water quality

To determine whether pollution is occurring, sanitary engineers check several key indicators of pollution. One of the most important indicators is a high biochemical oxygen demand, or BOD, combined with a low dissolved oxygen content in streams. The BOD measure indicates the amount of organic pollution present by measuring the oxygen-consuming ability of the waste. A high demand for oxygen means that the waste load is large; a low dissolved oxygen measure at the same time indicates that the load may be straining the waste-assimilation capacity of the stream. The oxygen content should be high enough to sustain fish and aquatic life.

Other important indicators of pollution include unhealthy concentrations of disease-producing bacteria, turbidity mostly from silt, unsightly floating and accumulated solids, obnoxious odors, color, and above-normal amounts of the nutrients that over-stimulate aquatic plant growth. All of these indicators are checked and tested to analyze wastes, and then to prescribe appropriate waste treatments and pollution controls.

Control of Pollution in Illinois

Water pollution control in Illinois is administered under the 1951 Sanitary Water Board Act, which declared it to be the public policy of the State to maintain reasonable standards of purity of the waters of the State consistent with their use, including their use for transporting and diluting wastes.

The Sanitary Water Board consists of the Directors of the Illinois Departments of Public Health, Conservation, Agriculture, and Public Works and Buildings. Two additional members are appointed by the Governor; one representing municipalities and one representing industry. The technical secretary of the Board is the State Sanitary Engineer and the technical staff are the sanitary engineers of the Illinois Department of Public Health. This board has the power to determine the existence of pollution and to establish regulations for municipal and industrial waste treatment and treatment facilities. Penalties can be imposed for violation of the Sanitary Water Board Act.

The method and degree of waste treatment required in Illinois depends upon the amount and kind of wastes, and upon the character and capacity of the receiving stream. Each situation is considered individually. The use of the water farther downstream also must be considered. It is not required that water be returned to the stream unimpaired in quality, and in most cases it is not economically feasible to do so.

The quality desired, and therefore the treatment needed, has been determined in part by classifying the uses of individual streams and separate portions of longer streams. Legitimate uses of streams change, and the citizens of Illinois have in recent years decided that an improved level of quality should be maintained.

Pollution control measures have been and will be adjusted to such changes. The increase in recreational use of streams and lakes for boating and fishing has required greater pollution control. Impoundment of streams in reservoirs as a source of public water supply also increases the need for higher degrees of sewage treatment.

In most cases, the dissolved oxygen content is the control in determining pollution, and the goal is to maintain stream quality that will support fish and aquatic life. Streams which meet this standard are suitable for use for water supply, recreation with partial body contact, and for wildlife or livestock watering. Use of lakes and streams for body-contact recreation such as swimming or water skiing requires more waste treatment and disinfection. It is recognized that some small streams in heavily populated areas cannot be maintained for all possible uses, but they can be managed so as not to create a nuisance.

The job ahead is great. Most rivers and streams in Illinois are polluted to some degree. None of them have been damaged beyond recovery—but none are suitable for swimming. In many Illinois waters good sports and commercial fish have disappeared, leaving less favorable species, and there are no fish in a few streams in southern coal mining areas polluted by acid wastes from mines. Fish kills, however, are usually the result of one-time accidental spills of toxic materials. Pollution is generally greatest near urban sewage outlets. Many streams have pollution problems in summer when the temperature is high and streamflow is low.

Clean streams and a high level of water quality must be restored and maintained if we are to use our water resources for multiple purposes. Our ability to make repeated use of water in effect increases the size of the resource. Thus, quality will actually determine the quantity of our usable water resources for the future.

FOR FURTHER STUDY

Water Agencies

A number of state agencies have responsibilities for the management and development of water resources in Illinois. The services of these agencies are available for consultation on water problems. Information from each agency is available upon request.

Division of Water and Natural Resources, Department of Business and Economic Development, Springfield, Illinois. The Division of Water and Natural Resources provides the State with the mechanism for coordinating its own efforts in water resources development and planning. Programs and activities of this Division include the preparation of a state water plan as a guide for future water management. This work is aided by the services of the Technical Advisory Committee on Water Resources.

Division of Soil and Water Conservation, Department of Agriculture, Springfield, Illinois. This Division administers the State Soil and Water Conservation Districts Law. It has the responsibility for developing and carrying on a water conservation program in cooperation with landowners and operators and with other agencies of federal, state, and local governments. Its water conservation program is carried on through technical help to the 98 organized soil conservation districts in Illinois. The Division provides supplemental land surveys and preliminary investigations on approved watersheds in the preparation of watershed plans and designs for works of improvement.

State Mining Board and Division of Oil and Gas, Department of Mines and Minerals, Springfield, Illinois. The Mining Board has the authority to prohibit the drilling of wells which would pollute fresh water supplies by oil, gas, or salt water. Permits must be obtained from the Board for drilling all water, gas, and oil wells and for plugging wells. The Division of Oil and Gas processes applications for permits to drill for oil and gas and water, and maintains records to insure an orderly development of our natural resources.

State Sanitary Water Board and Division of Sanitary Engineering, Department of Public Health, Springfield, Illinois. Water pollution control is the prime responsibility of the Sanitary Water Board. The Board reviews plans and specifications for proposed waste treatment facilities.

It also investigates sources of pollution and promotes water quality control by the routine sampling of all surface waters. The Division of Sanitary Engineering acts in a supervisory capacity relative to the sanitary quality and adequacy of proposed and existing public water supplies and water treatment and purification works. It is also responsible for the bacteriological safety of public water supplies and public swimming pools.

Division of Waterways, Department of Public Works and Buildings, Springfield, Illinois. The Division of Waterways designs and supervises the construction of projects authorized by state legislature, including dams, levees, sea walls, and other types of water control structures. The Division is responsible for the improvement, maintenance, or repair of state owned bridges and exercises regulatory control over all construction in the public waters of the State. It also maintains an inventory by county of all waters in Illinois and collects data on navigability and related subjects.

Divisions of Engineering, Fisheries, Game, and Parks and Memorials, Department of Conservation, Springfield, Illinois. The primary responsibility of the Engineering Division is to correlate all planning, engineering, construction, and land acquisition for the several Divisions of the Department of Conservation. These projects include park and recreational developments; facilities for public hunting and fishing; public access to major waterways and lake developments; water supplies, sanitation, power, and other utilities necessary for public use of conservation properties. The Division of Fisheries maintains a continuous inventory of all waters of the State, including natural and artificial lakes, ponds, and streams, and a field inventory of fish in streams in important watersheds throughout the State. It also studies fish conservation problems in connection with water pollution. The Division of Game determines the best possible use of all natural resources as they affect game numbers, distribution, and harvest. Its programs are directed toward the restoration of wildlife food and cover as a means of increasing game populations. The Parks and Memorials Division is responsible for acquiring, developing, and maintaining parks, conservation areas, nature preserves, and other scenic and natural areas for the enjoyment of the people of Illinois.

State Water Survey Division, Department of Registration and Education, Urbana, Illinois. The Water Survey is responsible for the scientific study of the water resources of Illinois. It studies the quantity and quality of waters and meteorological factors affecting water resources; develops methods of water use, measurement, and conservation; and seeks to extend the water sources that are becoming inadequate. Research activities of the Water Survey are organized under five sections: hydrology, chemistry, hydraulic systems, atmospheric sciences, and water quality.

State Geological Survey Division, Department of Registration and Education, Urbana, Illinois. The Geological Survey works closely with the Water Survey in the research and public service of groundwater supplies. Its groundwater reports apply primarily to the occurrence, movement, quality, and quantity of water in the various aquifers of the State.

Natural History Survey Division, Department of Registration and Education, Urbana, Illinois. The Natural History Survey is concerned with pollution as it affects fish and wildlife populations through Illinois. It is responsible for projects involving insects, plants, fishes, and wildlife, and the lands and waters they inhabit.

Selected Reading Material

The following books and pamphlets have been selected for further reading concerning water and special phases of water conservation problems. These materials are available in most school or public libraries, or can be obtained from the publishers. Publications of federal agencies may be obtained from the U. S. Government Printing Office, Washington, D. C. 20402.

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14

ILLINOIS

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