GROUND WATER IN INDIANA

Department of Natural Resources

Division of Water

NATURAL FEATURES OF INDIANA
GROUND WATER

By

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WHAT IS GROUND WATER?

Ground water, as differentiated from surface water, is water that percolates or flows beneath the surface of the earth. The legal definition as stated in Indiana's water law is, "all water filling the material openings under the earth's surface, including all underground streams, artesian basins, reservoirs, lakes, and other bodies of water below the earth's surface."

Ground water is so closely related to surface water that it is often difficult to clearly separate one from the other. For instance, water flowing underground and discharging from a spring or into a stream is ground water while below the ground surface, but immediately becomes surface water as soon as it reaches the surface. The reverse is true when water flowing overland or in a stream finds its way into the underlying ground-water formations.

ORIGIN

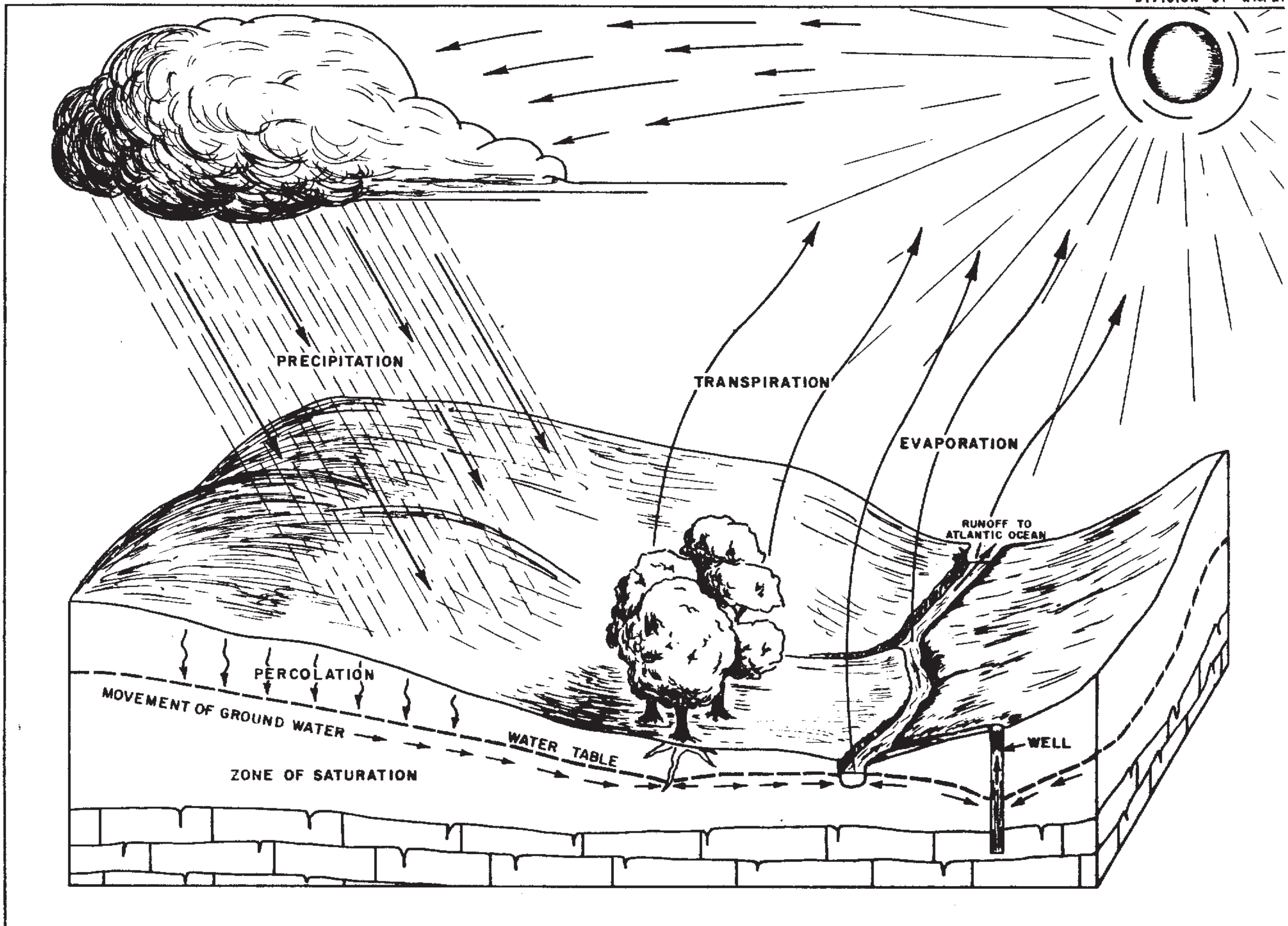
As precipitation falls on the earth, one of three things happens to it: it runs off the land surface to rivers and streams, it is evaporated or transpired by plants, or it soaks through the ground and becomes ground water (see figure 1). Eight to twenty percent of

Indiana's total annual precipitation (39.7") runs off the surface directly into our streams and eventually reaches the Atlantic Ocean, except for that which evaporates on its way. About 2/3 is lost by evaporation and transpiration, and the remaining 8 to 16 percent finds its way into the ground. That water which enters the ground moves to lower elevations, but at a much slower rate. Upon entering the ground, the water percolates downward through the zone of aeration until it reaches the water table, or the zone of saturation. Here, under normal conditions, the water will move laterally through the earth to a point of lower elevation and eventually to the areas of ground-water discharge such as springs, rivers, and lakes. It thus leaves its habitat in the ground, and becomes surface water, where it ultimately will be evaporated back into the atmosphere.

This phenomenon is called the hydrologic or water cycle. During this cycle water may be found in the ground, in streams, in plants, in food, or indeed, in almost anything, but it is always in the process of moving through the hydrologic cycle. Since water can be neither created nor destroyed, the water we are using today is the same water that existed since the beginning of time.

MODE OF OCCURRENCE

Ground water by definition occurs underground. It occupies the pore spaces and openings within the rock formations that make up the earth. Nearly all rock types, whether a compact shale or a loose sand have porosity. The amount, size and distribution of pore spaces can range widely. In many rock types in Indiana, porosity accounts for about 20% of the total rock volume. This means that if the pore spaces



HYDROLOGIC CYCLE

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could be filled with water, one cubic foot of water (7 1/2 gallons) could be added to a piece of rock having a volume of five cubic feet.

There is no such thing as an underground lake, and very few underground rivers in Indiana. Nearly all underground streams, such as Lost River, are found in the south-central part of the State and are the result of channels being formed in the rock by the dissolving action of moving water.

Because it is impossible to see ground water in its natural habitat, many erroneous ideas have been advanced about its behavior. However, ground water obeys the very same set of physical laws that surface water obeys. One of the most obvious facts about surface water is that it moves from one elevation to a lower elevation as it moves downhill. The same is true for ground water, and equally as obvious, is that ground water cannot move uphill.

As rain falls on the earth, part of it soaks into the ground, and percolates down through the zone of aeration. (See figure 1). Its movement through this zone is essentially straight downward. The rate of movement is controlled to a large degree by the type of soil through which it moves; the movement is slow through a clayey soil, and much faster in a sandy one. The water moves downward until it reaches the water table, or the zone of saturation. This may be a distinct horizon, or it may be a gradational zone. Once in the zone of saturation, this water begins to move slowly through the water-bearing formation, called an aquifer.

Ground-water movement is seldom uniform in direction or in velocity. Permeability of the aquifer, which in part determines the rate of movement, may vary greatly from place to place, even within short distances. Unlike surface water, movement of ground water is usually quite slow, and in Indiana the rate of ground water movement is usually expressed in inches per day. Velocities in the order of five feet per year to five feet per day are probably typical.

Figure 1 illustrates how water moves naturally through an aquifer. Under natural conditions, this water will "spill out" at the earth's surface through a spring or into a lake or stream.

Ground water can be induced to move through an aquifer by pumping a well. Withdrawal through the well has the effect of lowering the water level in the vicinity of the well, thus increasing the hydraulic gradient, causing the water to move through the aquifer and towards the well at a higher velocity. The lowering, since it occurs in all directions around the well, is called a cone of depression. The size and shape of the cone is dependent upon the rate of well discharge, the permeability of the aquifer, and recharge to the aquifer.

RECHARGE

A ground-water aquifer or reservoir may be likened to a bank vault. Just as a bank is a depository for large sums of money, an aquifer is capable of storing large volumes of water. Each may be tapped for withdrawal from time to time, and each must be replenished. This replenishment to an aquifer is called recharge.

There are two types of recharge, natural and artificial. Natural recharge occurs as precipitation falls on the earth and soaks into the ground. It also occurs when leakage from lakes or streams infiltrates the ground-water aquifer.

Artificial, or induced recharge may be defined as the process of replenishment of ground water through a works primarily designed for that purpose. Although no two projects are identical, all have the intent of inducing more surface water to enter the ground-water aquifer. This may be done through the use of pits, ditches, basins or stream beds which allow water to "leak" into the ground. Injection wells have also been used to pump water into the ground to recharge an aquifer.

There are several installations in Indiana where artificial recharge is used although it is not practiced to any large extent because the need for it has not arisen to date. At Anderson, a dam was constructed across Killbuck Creek for the sole purpose of impounding water to permit it to seep into the ground to recharge the city's wells. Christiana Creek was rerouted through Elkhart's well field for the purpose of recharging that city's well field. A pharmaceutical company in the northern part of the State discharges cooling water from its air condition equipment into a nearby pond, thereby recharging the aquifer from which it pumps water. While not designed as such, several cities and industries induce water into their well fields from nearby rivers by pumping large volumes of water which lowers the water table below the river level, thus causing water to be lost from the river to their wells.

WATER LEVELS

Throughout the years many statements have been made to the effect that water levels in Indiana have fallen to a dangerous level and that it was only a matter of time until the State would experience severe shortages of ground water. These statements generally have been made by individuals who had little knowledge of the facts or who knew little about the subject of ground water.

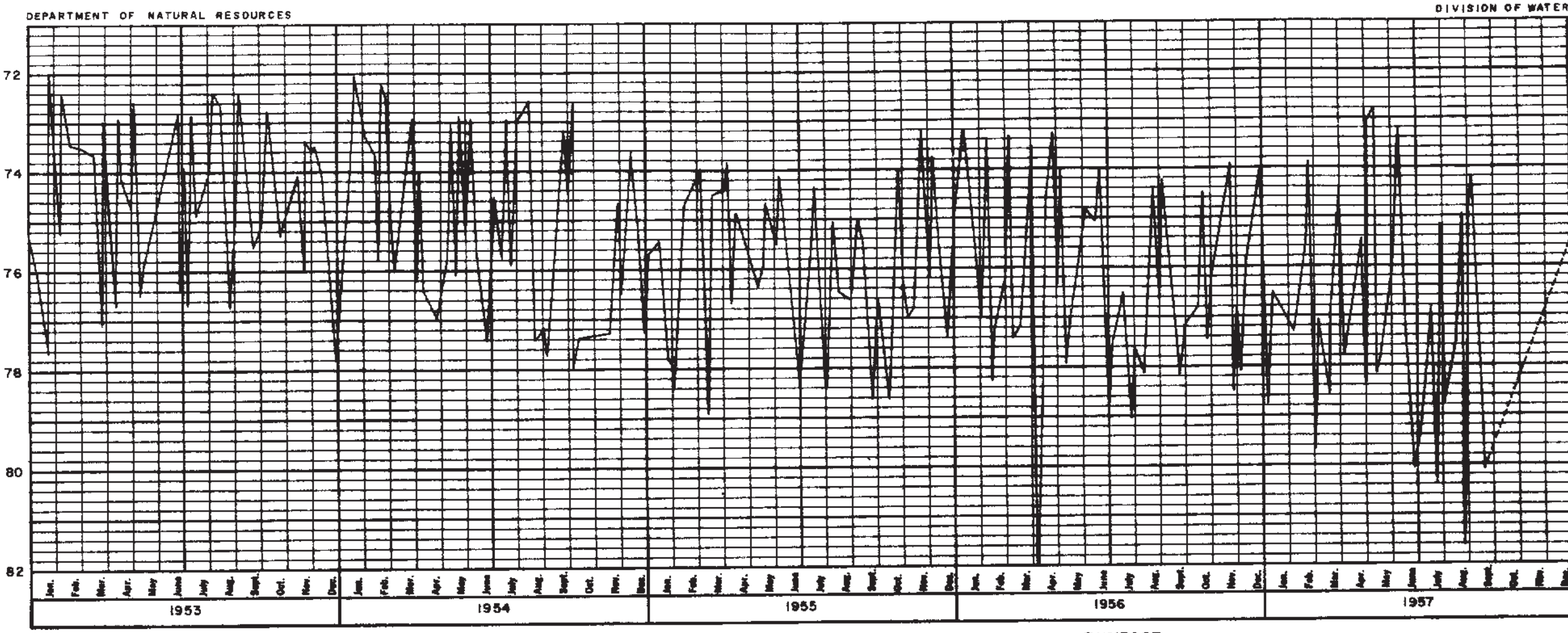
It is true that ground water levels have dropped in some parts of the State during the last century, but this has occurred only where man has either made changes in the surface of the land to accelerate the runoff of surface water or by withdrawing water from the ground through wells.

This is not necessarily harmful, however, because ground-water levels often must be lowered to fully utilize the water resources that are available in a given area.

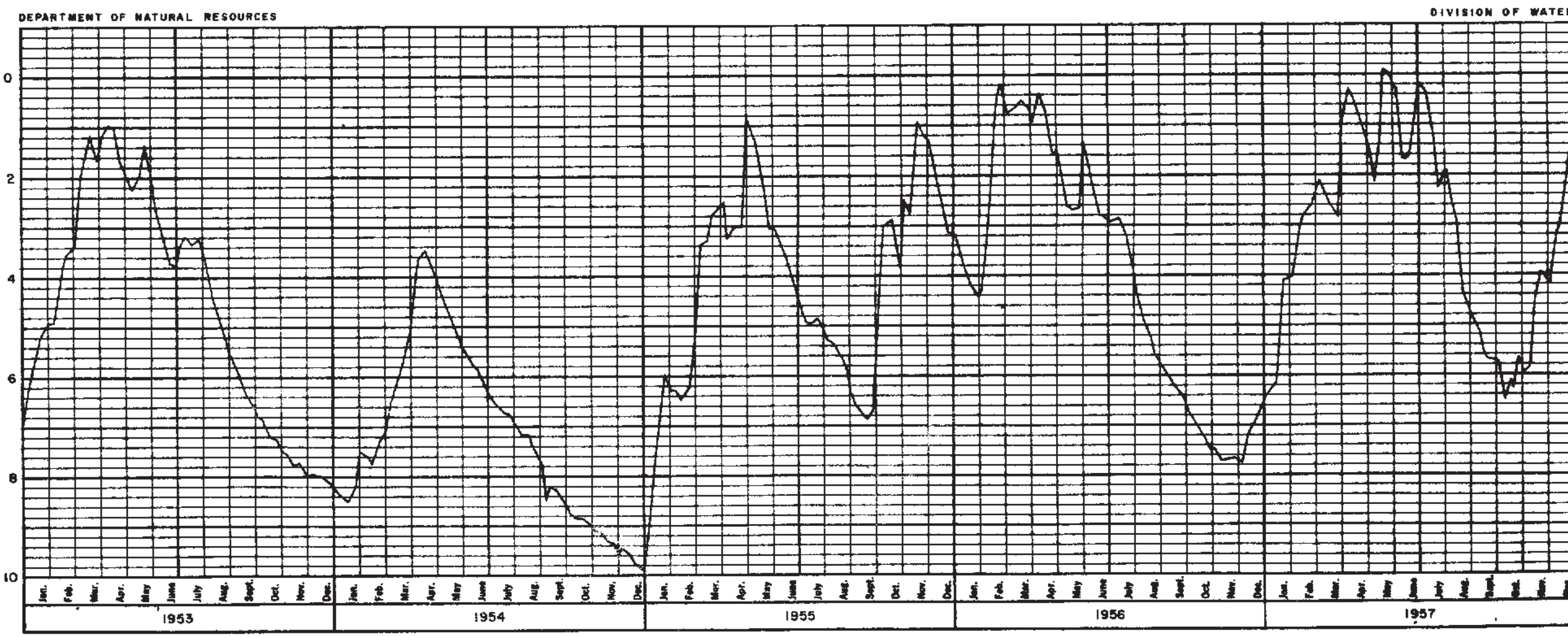
The water level in a well or aquifer is nearly always changing in response to the effects of natural or artificial influences. Water levels may be affected by precipitation, recharge from lakes and streams, by losses due to evaporation and transpiration, pumpage from wells, and by minor factors such as earthquakes, changes in barometric pressure, ocean tides, earth tides, etc. The potential effects of these factors must be considered in making an intelligent interpretation of water levels.

In order to determine the effects of these phenomena and to measure the long-term changes in water levels, or the water table as it is often called, a number of water-level observation wells have been established throughout the State. This program, which started in 1935 with 46 wells, has grown to 145 wells.

It is the long-term trend of the water levels as recorded by these observation wells that is important. This long-term trend is a function of the balance between the recharge to the underground reservoir and



HYDROGRAPH OF OBSERVATION WELL AFFECTED BY NEARBY PUMPAGE



HYDROGRAPH OF OBSERVATION WELL NOT AFFECTED BY PUMPAGE the discharge from it. In a situation where precipitation is above normal and discharge is minimal, water levels would be expected to rise. If, on the other hand, drought conditions exist and discharge is rather high, water levels will decline.

Water levels in Indiana have fluctuated considerably since the first observations were made in 1935, but in no instance has there been an indication that water is being mined or that ground-water levels have continued on a downward trend since the first observations were made.

Figure 2 is a typical hydrograph of an observation well that is not affected by pumpage, and illustrates the change in water level with time in response to changing conditions of recharge and discharge. It can be seen, that in general, the water level rises in the spring when recharge is high due to thawing of the ground and heavy precipitation, and falls in the summer and autumn when evaporation and transpiration losses are greatest and rainfall is low. Figure 3 is a typical hydrograph of an observation well that is affected by nearby pumpage. It can be seen from both of these hydrographs that during the five year period of record there is essentially no overall lowering of the water level or water table from the first year to the last.

It is the long term trend of water levels in observation wells that is important. As long as the water levels do not decline year after year there is no need for concern that water is being used at a rate greater than Mother Nature is replentishing it. In addition to this value water levels can be used to determine hydraulic characteristics of an aquifer and its potential as a source of water.

SPRINGS AND FLOWING WELLS

A spring is the concentrated discharge of ground water appearing at the ground surface as a current of flowing water. Seepage areas, as distinguished from springs, indicate a slower movement of water which may pond or evaporate as it emerges from the ground. There are many springs in Indiana, but the majority of these are found in the southern part of the State where water filling the caves and crevices in the rocks comes to the surface in the form of a "rise". Water in these cavities then issues forth as a spring.

The largest spring in the state, Harrison Spring near Corydon, is of this type. A maximum discharge of 250,000 gallons per minute has been measured from this spring. Fifteen large springs in Indiana and their minimum recorded flow, as measured in 1960, are listed in table 1.

Table 1. Minimum Recorded Flow of Springs in 1960

NAME	COUNTY	MINIMUM FLOW
Harrison	Harrison	12,375 gpm
Orangeville Rise	Orange	2,848 gpm
Rise of Lost River	Orange	2,745 gpm
Radcliff Springs	Washington	2,745 gpm
Frank	Harrison	1,600 gpm
Hunter	Washington	1,552 gpm
Van Cleave	Orange	1,237 gpm
Hamers Cave	Lawrence	1,125 gpm
Blue Springs	Lawrence	1,035 gpm
Avoca	Lawrence	900 gpm
Craven's	Washington	675 gpm
Organ Springs	Washington	562 gpm
Marengo	Crawford	450 gpm
Big Spring	Washington	450 gpm
Beck's Mill	Washington	450 gpm

Most springs fluctuate in their rate of discharge in response to variations in the rate of recharge. Perennial springs discharge throughout the year while intermittent springs discharge only during the portions of the year when sufficient ground water is recharged to maintain flow. Because of the variable flow of springs and the possibility of their being contaminated, they generally are not recommended for use as a water supply.

Flowing wells occur where ground water is confined at a pressure in excess of atmospheric pressure. Flowing wells are found in most counties, many of which are located in northern Indiana. These wells, when not put to beneficial use, constitute an unnecessary drain on the ground-water resources of the surrounding area. Artesian wells are the same as flowing wells except that the water level does not rise sufficiently high to flow. Contrary to popular belief, not all artesian wells produce mineralized water.

AVAILABILITY

In general, Indiana is blessed with a bountiful supply of ground water. With the exception of portions of southern Indiana, ground water may be relied upon to furnish an adequate supply of water for much of our populace. It is estimated that nearly one hundred thousand billion gallons of ground water are in reserve storage. This, plus the annual recharge from precipitation, if properly developed, can provide us with a dependable source of water to help meet our future needs.

Figure 4 is a generalized map showing the availability of ground water in Indiana. Four major ground-water provinces are defined.

In this report, availability of ground water is defined as the average maximum amount of water that normally may be obtained from

EXPLANATION

1 Wells with yields of several hundred gallons per minute can be developed in this area in the underlying sand and gravel formations; the wells generally are less than 100 feet deep. Most aquifers are hydraulically connected to a major stream and receive recharge from this stream. Yields as high as 2,000 gallons per minute have been reported, and there are more than 200 known wells each having production rated in excess of one million gallons per day.

2a Water-bearing glacial drift attains thickness of 300 to 400 feet in much of this area. Wells are completed in sand and gravel formations within the drift. Well depths range from less than fifty feet to more than 400 feet. Yields as high as 1,000 gallons per minute have been reported.

2b Most wells are completed in glacial drift, although some penetrate bedrock. Well yields of several hundred gallons per minute have been reported in many instances. Depths of wells range from fifty to 400 feet, with an average depth of about 150 feet.

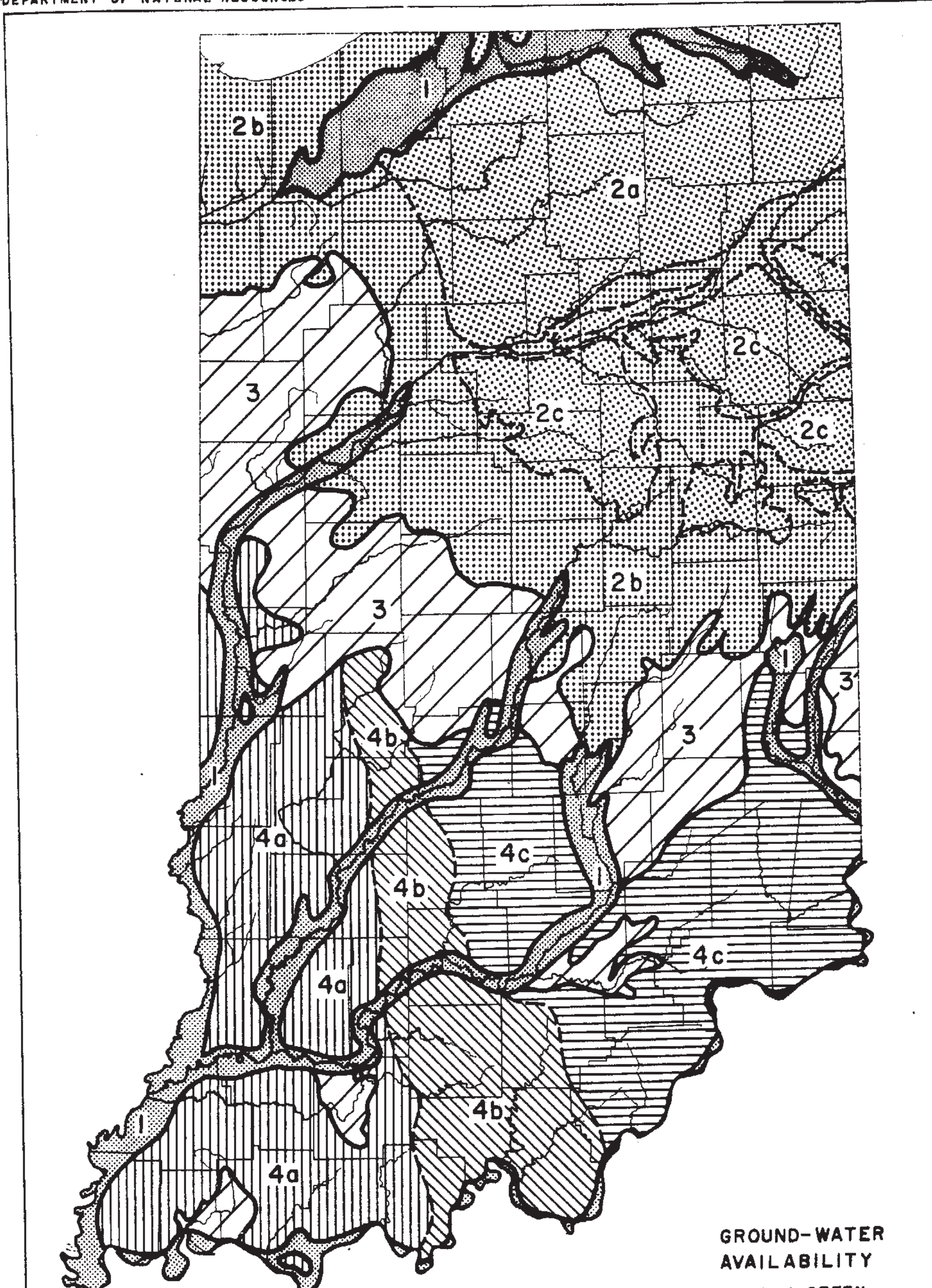
2c The glacial drift is relatively thin in this area and most wells are completed in the underlying limestone. Yields of 300 to 500 gallons per minute are obtainable, and well depths range from 50 to 400 feet. As a rule of thumb, most large capacity wells are deep, while domestic wells are not.

3 In general, adequate supplies from wells can be obtained for domestic and light industrial uses ranging from 10 to 100 gallons per minute. Conditions exist locally where larger yields can be obtained, and also where minimal yields are reported. The glacial drift is relatively thin, and the underlying bedrock is not too productive.

4a Most wells are completed in sandstone, although some are finished in coal or limestone. Wells are generally rated at less than 20 gallons per minute and numerous wells have been abandoned due to insufficient water. Depths of wells range up to 400 feet, but average somewhat less than 200-feet.

4b Due to the lack of water-bearing materials above the bedrock, wells are completed in limestone. Because of the heterogeneous nature of the rock, erratic ground-water conditions exist. Although the average yield of water wells is about five gallons per minute, yields as high as 30 gpm have been reported. Springs are common in many parts of this area.

4c With the exception of dug wells, most wells are completed in shale or limestone. Because these wells are "seep" wells, the wells are generally greater than 8" in diameter in order to provide sufficient water storage in the well. The average yield of wells is probably less than two gallons per minute. Cisterns and dug wells are common.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AVAILABILITY
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the water-bearing formations underlying a given area from a well which is properly sized and developed. The potential yield from this well will depend upon the geology of the area and the amount of recharge to the area. Because either or both of these conditions can vary with time or location, it can be seen that this estimated yield is an approximation of the potential of the area based on several types of available geologic and hydrologic data.

QUALITY

In recent years it has been recognized that the quality of ground water is nearly as important as the quantity. This is particularly true of water used by industry because of the effect certain minerals in the water may have on the product being produced.

The quality of ground water varies considerably in various parts of the state, but in general it is satisfactory for most domestic and industrial uses. However, much of the ground water has a relatively high iron and manganese content, and a good percentage of it is considered as hard. This is borne out by the fact that of 350 public water supplies using ground water, and serving 39% of the State's population, 113 have facilities for removing iron and manganese. There are ten cities that soften their ground-water supplies and one of the reasons for the number not being greater, is the expense involved in softening it. Some individuals using city water as well as those having individual wells, however, soften their water.

The U. S. Public Health Standards for drinking water limit the iron and manganese content to 0.3 parts per million. No standards for hardness have been established but generally water containing 0 to 60 parts per million of hardness is considered soft; 61 to 120 ppm as moderately hard; 120 to 200 ppm as hard and more than 200 ppm as very hard. It is not possible to give an average figure of the iron and manganese content of the ground waters of the state nor the average hardness because of the wide variation in these qualities depending on the location and depth of the well from which the water is obtained. The iron and manganese content will vary from zero to as much as 20 ppm and the hardness from a few parts per million to 1300 ppm.

Ground water contains other minerals such as chlorides, nitrates, sulphates, carbonates, etc. In water obtained from depths not exceeding 250 to 300 feet below the land surface, the percentage of these minerals is generally within the standards established by the U. S. Public Health Service.

Table 2 contains representative chemical analyses of ground waters found in the various ground-water provinces outlined in figure 4.

Table 2. Analyses of Ground Water

Province	Hardness	Calcium	Magnesium	Sodium	Iron	Chloride	Sulfate
1	339	90	24	14	2.0	16	79
2a	294	74	26	10	1.3	3	20
2b	274	61	23	42	1.1	20	31
2c	425	107	38	27	.8	7	218
3	375	92	37	24	2.0	6	103
4a	168	40	26	213	2.8	60	33
4b	410	92	50	39	.6	23	253
4c	289			39	.5	49	95

TEMPERATURE

Although the temperature of ground water varies only slightly under natural conditions, it may change due to man-made influences such as returning cooling water to the ground or recharging the ground with surface water. Because of its rather constant low temperature, ground water is widely used for air-conditioning and cooling purposes. The low temperature is often one of the major considerations in the use of ground water by industry.

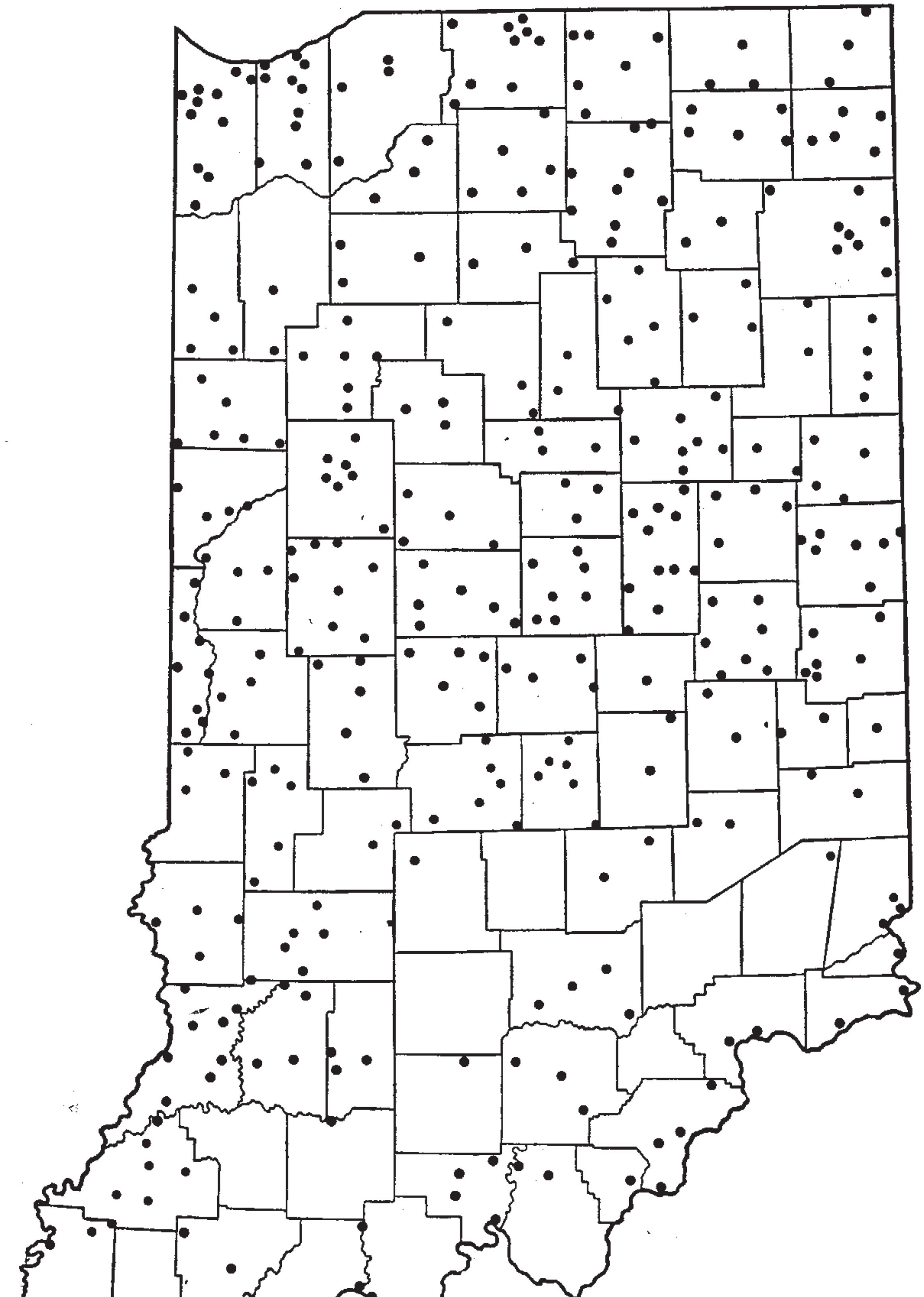
Although there are exceptions, it may be said that the temperature of ground water will generally exceed the average annual temperature by 2 to 3 degrees. In Indiana, ground-water temperatures range from about 52 degrees in the north to 58 degrees in the south. The temperature of ground water will increase slightly with depth but this is only in the magnitude of a degree for each 100 feet.

USES

In Indiana, we use about 12 billion gallons of water each day. Water use is increasing because our population is increasing and demanding more water. In 1950, the average municipal water consumption amounted to 120 gallons per day per capita; in 1975 it is expected to be about 174 gallons per day, an increase of 45%.

Of the total quantity of water used daily in Indiana, excluding that used by industry for cooling purposes, more than one half comes from the ground. There are 403 cities and towns in the state which are served by public water supplies and 350 of these or 87 percent use ground water. Sixty-four percent of the State's population uses ground water for its everyday domestic needs.

The trend toward suburban living has resulted in more ground-water use. Water requirements for domestic supplies (not on public water system) was 75,000,000 gpd in 1954, and are expected to increase to 148,000,000 gpd by 1975. Since nearly all individual supplies are



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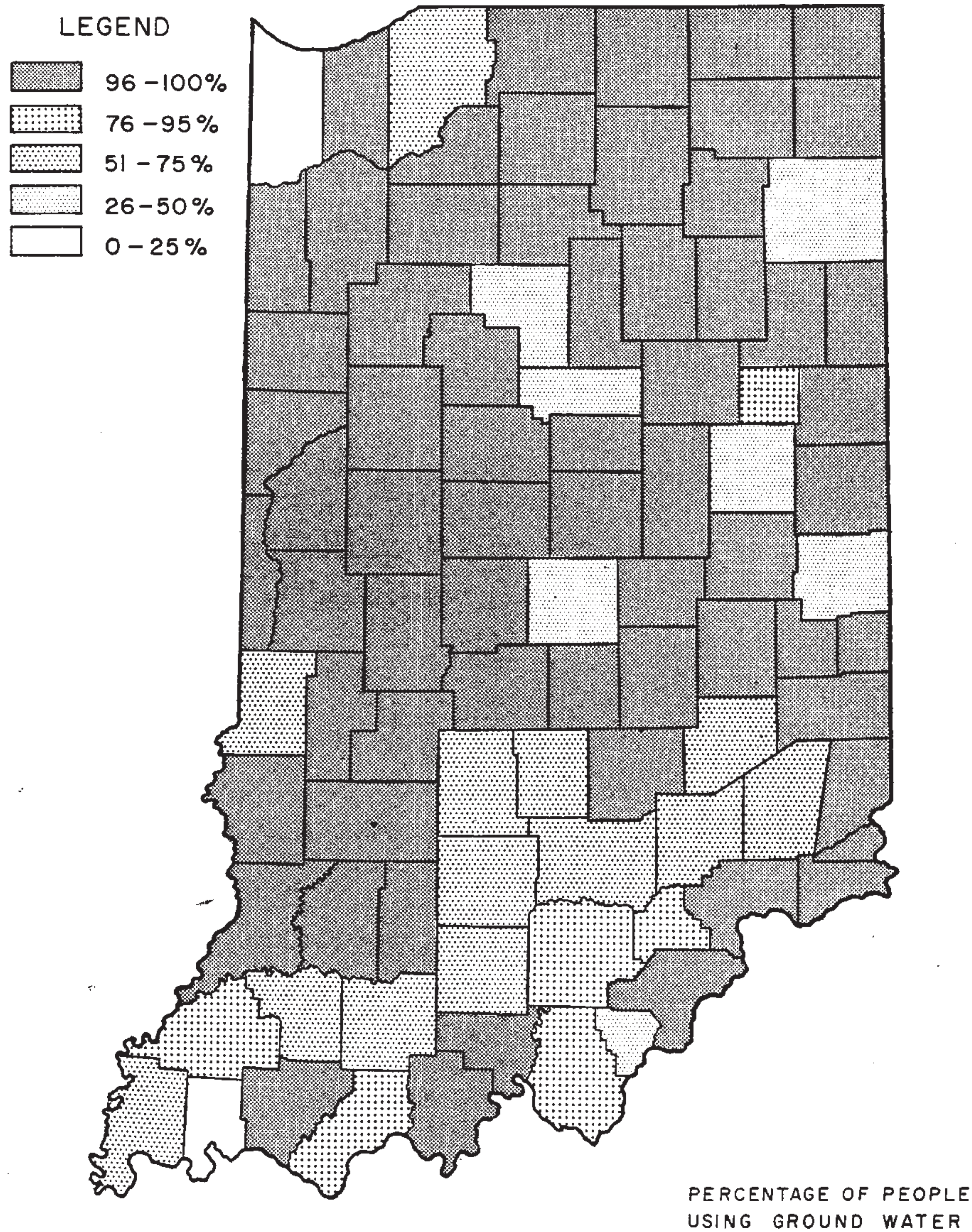
from ground water, this resource will be an important factor in the anticipated increase.

Industrial use of water has increased many fold during the past two decades, as has domestic and other uses. New manufacturing processes requiring large volumes of water together with the rapid growth of the steel industry and the building of larger and larger steam generating plants, both of which require vast quantities of cooling water, is the reason for this rapid rise in water use. Most of this water comes from Lake Michigan, the Ohio and Wabash Rivers; since it is used primarily for cooling purposes and does not have to meet rigid quality standards. However, many industrial concerns must have water of high quality, and in some cases of low temperature, and consequently use ground water if it is available. Presently, industry in Indiana is using approximately 2.6 billion gallons of water per day of which about 175 million gallons is ground water.

Ground water is an important source of water for irrigation. While rainfall throughout the State is generally sufficient during the growing season to produce good crops, there are years that this is not always true. In some instances; farmers have resorted to supplemental irrigation. Both surface and ground waters have been used for this purpose and during the drought years of 1953 and 1954 about 325 million gallons of water was used daily. Slightly less than half of this water came from the ground. Irrigation facilities have expanded since that time, but the use of water for this purpose has not increased as much as other uses because of more favorable rainfall conditions.

There are many other uses being made of ground water in addition to those already mentioned, and while the amounts being used for these


LEGEND
96-100%
76-95%
51-75%
26-50%
0-25%
PERCENTAGE OF PEOPLE
USING GROUND WATER

purposes are considerably less, they are important in the overall development and production of this resource. Potable ground water is being used to a considerable extent in some parts of the state to increase the production of oil by injecting the water into oil-bearing formations. Ground water is used for heating homes and buildings as well as in air conditioning. This use had grown rapidly during the past several years. Recreation is also placing an additional burden on the use of ground water for private swimming pools, watering golf courses and maintaining water levels in ponds and lakes used for recreation purposes.

GROUND WATER RIGHTS

It was not until 1947 that any attempt was made to control or regulate the use of ground water in Indiana by statute. Prior to that time the only law on the subject was common law based on the "English rule", brought to this country by the early settlers. Under this doctrine the owner of the land is considered to own from the center of the earth to the center of the heavens, and therefore has the absolute right to all of the water beneath his property. Because of the inequities resulting from this application of the English rule, many of the eastern states which originally adopted that rule have today replaced it with the doctrine of reasonable use. Under this doctrine, withdrawals of ground water may be limited on a reasonable use basis. Litigation over the use of ground water in Indiana has been limited and because of this fact it is difficult to determine the State's position on this matter, although it is generally considered by some authorities to favor the reasonable use theory.

In 1947, the General Assembly passed its first law attempting to regulate the use of ground water by legislative action. This law made it unlawful for anyone to remove more than two hundred gallons per minute from the ground and use it for air conditioning or cooling of air purposes; unless the water was circulated through cooling towers or other devices, returned to the ground through recharge wells, or a permit obtained as provided in the law.

The above law was repealed in 1951 and a more comprehensive ground-water law was passed to replace it. This new law was designed to conserve and protect the ground water resources of the State, to prevent their loss and waste and to limit and allocate the use of ground waters in all areas of the state where it is found that its use may impair or exhaust the supply or render it unfit for use.

In 1957 a law was passed which provided authority to prevent the waste of water from flowing wells. It also provided a means of protecting the supply of potable ground water from being exhausted or depleted in areas where such waters are being used to pressurize oil-bearing formations to increase oil production.

Still a further step in the regulation and control of ground water was taken when the 1955 Water Resources Law was amended in 1959 to include ground water. This law states that the general welfare of the people of Indiana requires that the water resources of the state be put to beneficial use to their fullest extent and the use of water for non-beneficial use be prevented. It also states that the water resources are public waters and subject to control and regulation for the public welfare as hereafter determined by the General Assembly.

A more recent law pertaining to the ground waters of the state is the 1959 law which requires all water well drilling contractors to be licensed and to keep a complete record of every water well that is drilled and to file such record with the state.

As the need for ground water rises, undoubtedly there will be a need for further legislation to assure the proper developement and use of this vital resource. Looking forward to this need, in 1961 the legislature created a Water Resources Study Committee to study water rights, resources and management. This is a continuing committee, and wisely so, because the problems that lie ahead in clearly defining and establishing the rights of individuals and others to the use and development of the state's ground waters and in guiding the General Assembly in the enactment of legislation that may be needed to insure the orderly development and management of this resource, are extremely complex and will require much thought and deliberation.

GROUND WATER PROGRAM

Many early annual reports by the Indiana Geological Survey and the Department of Geology and Natural Resources contained reports on wells, springs, mineral waters and other aspects of the ground-water resources in various parts of the State. In more recent years, similar reports were published by the Division of Geology, Department of Conservation, and in 1935 that Division published a report on Ground Water in Indiana. However, it was not until 1943 that the State had a formal program directed toward a state-wide study or investigation of its ground-water resources. At that time, the legislature passed a law authorizing the Department of Conservation to conduct an investigation and measurement of both the surface and ground waters of Indiana and appropriated funds for that purpose. It also authorized the Department to cooperate with the United States Geological Survey and other agencies in making this study.

The program has grown steadily, and a vast store of basic data needed to appraise and evaluate our ground-water resources has been accumulated. A network of 145 observation wells to obtain data on the fluctuation of ground-water levels throughout the state have been operated and maintained since 1935. Numerous aquifer-performance tests have been conducted to determine the hydraulic characteristic of different types of water-bearing formations at various locations. Detailed investigations have been made of the ground-water resources of 28 counties and reports of these studies have been published or are in the process of being published. These reports contain information on water levels, water quality, water sources, well records and the availability of water in the various water-bearing formations within each county.

Recently a program has been initiated to prepare and publish colored brochures with county maps showing the availability of ground water in the county. These atlases will also contain information on water quality, water usage, geology, geography, climate and population.

Another part of the overall program is to make investigation of local problems throughout the state. These are made primarily to assist individuals, industrial concerns, cities and towns and others in solving their ground-water problems. Such diverse projects as deep-well waste disposal and oil-field water flooding with potable ground water are included in these surveys.

Future

Quantitative studies are underway to determine how much ground water is available for use. Our increasing population is demanding more water, and because of contamination and the limited number of reservoir sites in our state, ground water affords the most dependable and the safest source of water. Since it is not as vulnerable to radioactive fallout as surface waters, it would play an important role in the event of a nuclear disaster. With new methods of water treatment, the vast supply of deep mineralized water (estimated to be greater than the reserve of potable water) may become a new source of supply. In addition to this potential supply there are still large quantities of untapped potable ground water that need only to be located, defined, and developed. In a world so acutely dependent upon water, we cannot afford to overlook such a vital source; (ground water) our most dependable source of water.