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THE CONSERVATION OF UNDERGROUND WATERS

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Importance of Water.— Ranking with the soil and the atmosphere, water is recognized as being one of the absolute essentials of existence. We are all familiar with the fact that where water is absent — or unavailable, which is equivalent — life likewise is absent or nearly so. It is difficult, perhaps needless, to decide which is the most necessary, soil, air, or water, all are so intimately interwoven into the complex relationships of life. Not only is that water which is exterior to the organic creation an essential to the continued well being of that creation but much the greater bulk of animal and vegetable tissue is composed of water. It is estimated that of annual plants, three-fourths of the substance is water; of perennials, three-eighths is water. Eighty per cent of animal tissue is water, and this ratio holds good with regard to the body of man himself. The gray matter of the human brain — the most highly developed and specialized living material on the planet — is said to consist of 83.5 per cent of water, leaving only 16.5 per cent of solid matter, so called (Van Hise).

The amount of water consumed by animals and plants in their growth and nourishment is truly remarkable. "The average man of 150 pounds weight ingests each year about 264 gallons of water or 35 cubic feet, the weight of which is more than a ton" (Van Hise). Do we of Iowa realize that to produce a bushel of our world-famed corn there is necessitated the evaporation from the soil and the transpiration from the plants of ten to twenty tons of water? Or that the pound of beefsteak about whose price we grumble so severely required from fifteen to thirty tons of water in its production (McGee)? Multiply these figures by the beeves grazing today in Iowa pastures and over the Great Plains and by the millions of acres of corn and grain waving in our fields or standing in orderly shocks and you gain some conception of the enormous volume of water that enters into the life of the world.

Source and Distribution of Ground Water.— Of course the source of the water of the earth is the rainfall and it is interesting to note that over the United States this averages about 1500 cubic miles each year, enough to cover the national domain to a depth of thirty inches. In Iowa the rainfall averages a little more — nearly thirty-two inches, ranging from thirty-four inches in southeastern Iowa to twenty-eight in the northwestern portions. This means that on the average upon each of Iowa's 35,575,000 acres there falls annually 116,000 cubic feet of water, a total for the state of twenty-eight cubic miles.

Now what becomes of this vast quantity of water? The experts tell us that substantially one-half evaporates and is returned quickly to the atmosphere. One-third runs into the rivers and back to the sea and hence is known as the run-off. The remaining one-sixth is consumed by plants or, escaping them, goes deep enough to join the permanent body of water beneath the surface, the underground reservoir, the ground water. It is this latter one-sixth that we are to consider just now.

Let it be understood that despite popular conception there are no extensive underground lakes and very few subterranean streams. Such as do exist are gathered chiefly in the relatively rare caverns and devious passageways in the upper portion of the earth's crust. The great body of the ground water is diffused through the pores and crevices and other small openings in the rock and soil of the solid earth. The upper surface of the ground water — the ground water level or water table — is somewhere near the surface of the earth. The lowest extent of the ground water is about six miles, below which depth the pressure of overlying material is so great as to render the subjacent rock impervious. Most of the waters in much the greater portion of this zone must, however, remain permanently inaccessible to man through any means. It is only the water content of the topmost few hundreds of feet which can be counted on to be of any service to humanity or indeed to life forms of any kind.

What then is the amount of available ground water, how may it be best utilized and by what means shall we seek most intelligently to conserve it? These are the questions which most concern us in this inquiry.

Relation to Rock Strata.— Of the stratified rocks of Iowa the Sioux quartzite contains probably less than one per cent of voids, the limestones contain one to five per cent and the sandstones contain five to twenty-five per cent. Doctor McGee has estimated that the amount of water in the outer one hundred feet of the rocks of the United States is sufficient to cover its entire area to a depth of seventeen feet. This is equivalent to the rainfall for seven years. Since Iowa is in the region which receives at least an average amount of the total rainfall of the United States we may accept these figures as being substantially correct for our state. It appears then that there is no lack of ground water, that the total capacity of the reservoir is very large and that rainfall is reasonably sufficient to continually replenish the supply.

If we consider the relation of the various strata of Iowa to her ground water supply we shall find that the glacial formations, the clays and sands and gravels transported and spread out by the great ice-sheets of Pleistocene time, form one of the most important, if not actually the greatest of the aquifers, or water-bearing formations, of our geological column. Leaving out of consideration for the moment the water used by plants, which over most of the state is drawn directly from glacial drift materials, most of our rural population depends entirely or nearly so on the drift for its water supply. This supply is drawn largely from wells, in lesser measure from springs, to some extent from so-called surface waters, which, however, are replenished in part from the underground supplies. Again, many of our cities and towns are supplied from the drift — including here the sands and gravels found as pockets in the clays or lining the valley floors. Notable examples are Des Moines, Council Bluffs and Sioux City in part, Le Mars, Webster City, Chariton, Atlantic, Muscatine and many others. It is doubtless true that more than half of the state's inhabitants depend directly on the drift materials for their supplies of water.

Beneath the drift covering — the mantle rock — lie the great series of the bed rock. All of these strata contain water in different amounts, the shales scantily, the limestones in fair abundance in crevices and fissures and pores, the sandstones in bountiful supply. Hence whenever a sandstone is penetrated by wells it is more than likely to supply a goodly store. The Cretaceous sandstones of western Iowa, the Des Moines sandstones in the central counties, the St. Peter, the New Richmond and the Cambrian sandstones in northeastern and southeastern Iowa, all of these beds yield water in large measure to the wells which are sunk into their depths. The waters from some of these strata are rather heavily mineralized, it is true. And this mineralization is increasingly heavy at greater distances from the regions of outcrop of the strata. But it is nevertheless true that the combined

Jordan-St. Peter field is the greatest artesian basin in the United States. These formations outcrop over 15,000 square miles in Wisconsin, Minnesota and Iowa. The rainfall which they receive is transmitted readily through their porous strata and percolates hundreds of miles beneath the surrounding states. Many of the towns of eastern and northeastern Iowa receive a bountiful and excellent supply of water from these stored-up sources. Among them we may mention McGregor, Dubuque, Sabula, Clinton, Manchester and Charles City. Even points as far distant from the outcrop as Keokuk, Centerville, Stuart and Denison have artesian wells fed from these great aquifers.

The sandstones of the Des Moines stage are quite strongly mineralized and are not much used for municipal supplies although they furnish water to a number of country wells. The Cretaceous sandstones supply a number of wells in the area of their extent, among them being those at Cherokee and Guthrie Center. Possibly also some of the wells at Sioux City are fed from these beds.

The various limestone strata of the state also furnish large supplies of water to many shallow wells, to abundant springs in the areas of their outcrop and to numbers of fairly deep wells which penetrate them for a few hundred feet. Such wells are those at Oelwein, West Union, Cedar Falls, Forest City and elsewhere.

It has been estimated that seventy-five per cent of the population of the United States depends directly on underground waters (Mendenhall) and a review of conditions in our own state would lead to the opinion that an even greater percentage of Iowans use this source, since only a relatively small number of cities and towns depend on surface supplies such as rivers, lakes and impounded waters. The brief discussion here given will show, it is hoped, the importance and value of the ground water for domestic and industrial uses and yet it is estimated that the amount used annually in the United States is equal to only about one per cent of the total flow of the streams of the land for the same period of time.

Use of Ground Waters by Plants.— Turning for a moment to consider the use of ground waters by plants: it takes but little thought to realize the importance of the underground supplies in supporting this part of the living world. Doubtless plants derive a portion of their needful moisture directly from the rain as it falls and from the run-off on its way to the streams. But much the greater part of the water used by vegetation must come from beneath the surface and must be drawn in by the root systems of the plants themselves. During the seasons and periods of abundant rainfall, when the groundwater level is high and the root systems are laved with moisture, the process of keeping each of these miniature waterworks systems in successful operation is a relatively simple one. But during dry seasons, when the water table has dropped down below the reach of the major trunk lines, below even the minor feeders, then the more complex operations of capillarity must come into play.

Capillarity or capillary attraction is the adhesive force by which moisture is held in small openings in opposition to the force of gravity. This force is sufficient to hold capillary water about five feet above the water table in ordinary soils, the actual distances ranging from four feet in coarsely sandy soils to eight feet in finely sandy or clayey soils (Meyer). It is necessary, of course, if life is to be sustained, for connections to be maintained between plants, roots, capillary water and gravity water — the portion below the water table. If this connection be broken for any extensive period, death must ensue. Because of this fact many plants develop root systems several times more extensive than that part which is above ground. Thus some of the grasses in the western arid regions send their roots down five, six and seven feet into the ground in search of moisture, and it has been said that alfalfa has been known to grow roots even longer than these. The amount of water actually used by plants is probably not known, but it must be very great. The amount of transpiration from the foliage of forest trees — that is, the water which passes back into the atmosphere from the pores of the leaves — is stated to vary from 1000 to 20,000 pounds per day per acre during the growing season, while the transpiration from the leaves of maize in the production of a bushel of corn is said to be about 5000 pounds (Van Hise). It is evident then that great quantities of moisture are used by the vegetable life of the land.

Another important use of ground water is in preserving and stabilizing stream flow. While the streams are fed primarily by the run-off, their flow is maintained during periods of little or no rainfall, which with us includes a majority of the days of the year, by springs and by seepage from the rocks and soil. The water which escapes in this way and finds its way back to the sea, amounts to a great deal and must contribute very largely to the eleven or twelve inches of run-off which the upper Mississippi valley furnishes to the great master stream.

Conservation of the Ground Water.— How then may we properly conserve our stores of underground water? Obviously the problem resolves itself into making the most efficient and at the same time the most economical use of the supplies with which Nature has so beneficently endowed us. Not to use them is to waste them. To fail in making them serve to the utmost in the advancement of all material and social welfare is as much criminal negligence as is their wilful or careless dissipation. Hence the question is not, Shall we use them? but rather, What is the best method of utilization? There are two chief lines along which their utilization will proceed, namely domestic and industrial uses and agricultural uses.

For the first of these classes, domestic and industrial uses, the quality of serviceable water is rather severely limited. The amount of water held in solution, either of solid or of gaseous matter, must be relatively small in order not to interfere seriously with its palatability, its effect on the human body, its action in steam boilers and other industrial machinery. These limitations have prevented the use of many supplies which were abundant in quantity and easily accessible, at the same time necessitating greater drafts upon less abundant but more desirable supplies. Thus here the problem is the complex one of securing water that is abundant, is easily put where it is needed and is of the proper quality.

Living plants are less fastidious in their demands than are mere mechanical plants. Provide them with almost any kind of water and they will take from it what they need and reject what is useless for their growth. Here the problem is largely that of keeping a supply of water within capillary reach of the roots. Of course these statements cover only ordinary ground water, not acid waters from mines, or industrial wastes and similar classes.

The Effect of Population Increase.— The rapid growth of population in the upper Mississippi valley, as elsewhere in the United States, has made necessary increasingly heavy drafts upon the water supply. So long as the population was largely rural or in small towns the supply of water needed was drawn from the streams or from shallow wells. Furthermore there was relatively little pollution of these sources. With the centralization of population and the rapid growth of large cities there have come not proportional increases in the demand for water but a demand which has grown by leaps and bounds, in geometric ratio. Application of water to sanitary purposes in the home, public sewage systems, enormous manufacturing industries, all these call for usage of amounts of water which to our forefathers would have seemed unbelievable. The ordinary shallow well in the back yard is not only insufficient, it is inefficient, incapable and unsanitary. The great system of galleries, the battery of large wells, the deep bores piercing the aquifers far underground, these have taken its place. The shallow well of our fathers, the clear sparkling streams and ponds of our childhood are gone or, what is worse, are polluted beyond use or are in danger of contamination.

The Effect of Agriculture.—Paralleling this enlarged demand for water there has come a change in surface conditions which has diminished the supply or at least has tended to interfere with its replenishment. Agriculture, either by carelessness or by wrong methods or in part perhaps by necessity, has caused an increase in the run-off, thus lessening the amount which should seep into the ground, while at the same time filling the stream channels with the richest of the surface soil. The breaking up of the sod which held back the rain as it fell so that it might be absorbed instead of washing gullies in the soil; the cutting away of the forests from the steep slopes, permitting the gullying and gashing of the hillsides; all of these have acted counter to the needs of the state — they have wasted and lessened its available water-supply when it should have been conserved and increased.

Doctor Beyer stated in his Presidential address before the Iowa Academy of Science that "The records show that the average lowering (of the water table) for the entire country is about nine feet and for Iowa some twelve and a half feet during the fifty years preceding 1910." Happily he stated further that "The rate of lowering was highest during the early stages but appears to be proceeding at a diminished rate." I firmly believe that this lowering is due to the practical loss of so much rainfall because of the increased run-off mentioned above as much as to the increase in the use of water. If some means can be found to check what is practically a waste of water an important step will have been taken in the conservation of the ground water supply.

Most of the water that is used by plants is returned to the atmosphere and is useful in maintaining atmospheric humidity and rainfall. Most of that used for domestic, civic or industrial purposes ultimately joins the run-off and is of little further immediate direct service. Hence a more conservative use of water by man will go far toward reducing this alarming lowering of the water table which is such a vital factor in the preservation of all life. If as has been stated, "the upper level of the ground water is not far from the limit of its availability for crop growth" (Beyer) it is evident that the condition is really alarming and must be remedied. It is not only the crop grower who is concerned. The crop consumer is equally vitally concerned. He too must take steps to retard and if possible prevent the catastrophe that seems to be impending.

Another element which, although necessary, has assisted in lowering the water level, is artificial drainage. Doctor Beyer, in the address to which reference has been made, urges strongly the abandonment of the open ditch as it both increases the run-off and wastes valuable land. Tile drainage, on the other hand, equalizes the run-off while reducing the wastage of the land. Furthermore by the very act of lowering the water table a few feet it reduces the losses through evaporation. Probably the greatest part of the work of drainage, with its consequent lowering of the water table, has been completed, so that it will not be a serious factor in the future.

It is clear that agriculture must be made to conserve soil moisture rather than dissipate it. How shall it be done? The details are for the trained agriculturist; only a few principles can be given here. Soil wastage must be stopped. Soil conservation must be enforced. Deforestation must cease or at least be very intelligently practiced and furthermore it should be accompanied by reforestation and even by the enlargement of the forests and groves. Proper treatment of the soil in plowing and in cultivating of crops will go far to preserve the water which is brought up by the great centrifugal pump, capillarity, and to prevent its excessive evaporation. Keeping the surface of the soil of the field loose and fine, fall plowing, allowing a field to lie fallow for a time; these all help in increasing percolation and reducing run-off. In spite of the great amount of transpiration from vegetation a cover of plants reduces the amount of evaporation from a given surface in a large degree. Let me cite the following relative rates of evaporation as given by Meyer. He says: "Considering the rate of evaporation from the bare ground surface at a given mean temperature as 1.0, the rate of evaporation of free moisture from the ground in grain fields may tentatively be taken as 0.8; for grass land 0.7; for light forests, brush and second growth 0.6; and for dense forests with abundant herbaceous vegetation from 0.2 to 0.4."

From our cities and towns in all quarters the cry is going up: "Our water supply is diminishing, our wells are going dry!" What does it mean? What are we going to do about it? From newspaper items and from official correspondence it is evident that everywhere the situation is becoming acute. At the present moment at least three of the important cities of Iowa which have depended on deep well supplies are looking anxiously for other sources, namely Mason City, Fort Dodge and Waterloo. The heads of the wells have fallen so low that it is becoming out of the question to depend on them much longer. Towns with large shallow wells are being forced to dig more wells or use surface waters. Towns dependent on impounded waters are finding difficulty in maintaining necessary reserves. We cannot increase the rainfall; we cannot find a substitute for water, although many establishments for that purpose are insistently thrusting their wares upon our notice. We must then adopt the only remaining recourse — conservation. The writer recalls listening while a graduate student at the State University to a paper on the water supply of Buda-Pesth, Hungary, in which the speaker said that that system furnished two gallons a day per inhabitant. The head of the engineering department of the University in commenting on the paper stated that the consumption in Iowa City was eighty gallons per capita. The daily average consumption for Des Moines is eighty-one to eighty-five gallons per person. Does this point a moral or adorn a tale? In the flowing well district of the artesian basin wells are left flowing from year end to year end. We of central Iowa are suffering for this wastefulness.

The way in which agriculture may help in conservation has already been discussed. In addition our forests are an important factor. It is a proven fact that nothing aids more in the retention and stabilizing of ground moisture than do the forests. In addition to all their other attractive features they rank as one of the great conservers of our water reserves. This they do by checking the run-off, by lessening evaporation, by preventing soil wastage with all its attendant evils. They not only stabilize the stream flow, maintaining it when the run-off fails; they increase the supply of ground water and yield it when it is most sorely needed. The advocate of forest preservation can advance arguments to appeal to every class, whether the so-called practical man, the idealist, the nature lover, the artist, the technical expert or the mere pleasure seeker. To all there is some feature which will carry weight. And to none is the movement to establish a great system of forest preserves, of parks big and little, of more importance than to those whose concern it is to see that the supplies of pure, healthful, life-giving water do not fail. Therefore it is well that we give thought to the careful and timely consideration of every plan that will tend to the betterment of living conditions by bringing Nature closer to Man and making her serve him more completely.

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