THE HYDROLOGY OF INDUSTRIAL AND MUNICIPAL WATER SUPPLIES IN ILLINOIS

BY

WINFRED D. GERBER

State Water Survey, Urbana.

In the dictionary published by Funk and Wagnalls, "hydrology" is defined thus: "The branch of physical geography that treats of the waters of the earth, their distribution, phenomena, properties, and laws. As used by the United States Geological Survey the term is restricted to subterranean water-resources." Since the broad definition includes *distribution, phenomena,* and *properties,* consideration will be given to some factors which are more physical than technical, more necessary than theoretical.

Research and scientific investigations are producing so many startling results that the public generally has come to expect a thrill on the front page of the paper each day, and the day is utterly ruined if the thrill is not delivered along with the morning toast and coffee. It takes but a moment's reflection to realize that all this excitement over so many and varied spectacular discoveries is distracting public attention from many commonplace things which in reality are of vastly more importance to the well-being and prosperity of the citizens of this and other countries.

The radio, automobile, telephone, railways, aeroplanes, electricity, and many other developments of the present age have practically become necessities, and yet there was a time not so long ago when they did not exist; and if they all were suddenly removed now, life could and would go on, although it might take some time to become adjusted to such a revised order of things. The discovery of many minerals such as gold, silver, tin, iron, coal, oil, gas, etc., have each brought about tremendous excitement and activity within the zone of their respective influence, but did anyone ever hear of people becoming excited over the bringing in of a new water well or the completion of a water treatment and purification plant? Apparently water is too commonplace to be responsible for any undue excitement; except in a reverse order, as it frequently happens that residents of a community bitterly oppose the installation of a public water supply and distribution system. It is hard to understand why anyone should oppose the development of such a system, for it has been quite effectively demonstrated that for a municipality to thrive under

the present competitive conditions it must have an adequate supply of water, which not only must be pure and healthful for human consumption but must be soft and *low in its mineral content* if it is to be attractive from an industrial view-point.

Cost of Water

No matter what it costs, water of good quality is never expensive; in fact, it is the cheapest necessity on the market. As an illustration, assume that a community of 1,000 population desires a water supply system that will cost $30,000 and that they propose to pay for it in 10 years out of the sale of water. The total interest charge at 6% for the 10-year period is in round figures $9,000, or a total of $39,000 for principal and interest; truly a considerable sum when viewed as a single item. To complete the payment of principal and interest in 10 years would thus require an annual payment of $3,900. Of course, the plant would need attention, and as is usual in such cases a part-time attendant together with maintenance and repairs, costing say $1,100, must be included, making a total of $5,000 per year to be met out of water revenues.

In a town of 1,000 people an average of 60 gallons per day per capita is likely liberal, but this discussion is more concerned with presenting a picture for argument's sake rather than submitting a financial budget. Sixty gallons per person per day for 1,000 persons equals 21,900,000 gallons per year, a quantity which if sold at 22.8 cents per 1,000 gallons will produce an annual total of $5,000. One thousand gallons weighs 8,333 pounds, or 4 1/6 tons; therefore, each ton of water delivered in the house costs but 5½ cents. What *necessity* can be purchased and delivered on an instant demand for 5½ cents per ton or even 25 cents per ton? It may be that difficulty is experienced in visualizing how much water is in 1,000 gallons. A cubical tank holding just 1,000 gallons measures approximately 5 feet 1¼ inches on each side. A block of water 5 feet cube for 22.8 cents. If this were frozen into ice retailing at 60 cents per 100 pounds, the cost would be $49. Coal of fair quality may be purchased in certain parts of Illinois for $3 per ton; water, if sold at this price, would carry a rate of $12 per 1,000 gallons.

Quantity and Quality.

Illinois is nearly surrounded by water, as a glance at the map will quickly prove. Even in the vicinity of the eastern and northern boundary lines, particularly the northern, there is much water to be found in separate lakes and streams. In addition, there are several good-sized river systems within the state. The Illinois River system, of course, is the largest and most far-reaching, but there are in addition the Rock,

the Kaskaskia, the Big Muddy, the Cache, the Saline, the Little Wabash, and the Embarrass rivers, all of which have considerable territory within their respective watersheds—to say nothing of the many small streams which discharge directly into the Mississippi or the Wabash.

With all this water in and around the state, and being blessed with a fairly ample annual rainfall, it may be small wonder that many citizens do not recognize that certain sections may have difficulty in obtaining a water supply of adequate quantity or of a quality acceptable as an incentive to municipal and industrial development. Water, like many minerals, is generally found associated with others; that is, because of the solvent ability of water, it takes into solution more or less of the other minerals with which it has been in contact. In certain parts of the state the amount of mineralization of the water supply is relatively low, while in other localities it is high.

The opportunities to secure water are not the same in all parts of Illinois; in fact, there are three sources of water which rather distinctly divide the state into three zones: a northern zone, a central zone, and a southern zone.

Northern Zone.

The northern zone includes that portion of the state extending from the Illinois-Wisconsin boundary southward to a line crossing the state approximately through the cities of Onarga, Fairbury, Elmwood, and Stronghurst. Within this area it is possible to secure water supplies from deep or rock wells. In this zone the water-bearing rocks, which are in order from the surface down, Limestone, St. Peter Sandstone, Dresbach Sandstone, and Mt. Simon Sandstone, have a gentle inclination downward from west to east and from north to south, the latter being more marked than the former. In the northwest portion the St. Peter Sandstone has been found within 40 feet of the surface. The outcrop, or absorption area, of this sandstone makes an irregular pattern in southern Wisconsin and along a comparatively narrow streak from some 25 miles east of Madison, Wisconsin, northerly to Menominee, Michigan. The Dresbach and Mt. Simon sandstones are members of the Cambrian system, and their absorption area covers a very considerable portion of central Wisconsin, extending from a line between Madison and Prairie du Chien northward to Wisconsin Rapids, with two prongs one northeasterly through Shawano to the northeastern boundary of the state and the other of greater width reaching as far to the northwest as Shell Lake.

Considering the quality of the water drawn from the St. Peter sandstone, it is interesting to note that in the north tier of counties the

FIG. 1.


MAP
OF
ILLINOIS
SHOWING
ROCK WELLS
Municipal Wells
Municipal Softening Plants

FIG. 2.

waters are harder and contain more carbonates for those wells west of Rockford than for those east. Water from the Dresbach does not show this geographical demarkation, though there are considerable differences in the hardness, residue, and alkalinity in the various wells in this strip of counties. The waters from wells penetrating the Mt. Simon sandstone show an interesting reversal of form; whereas the St. Peter water was

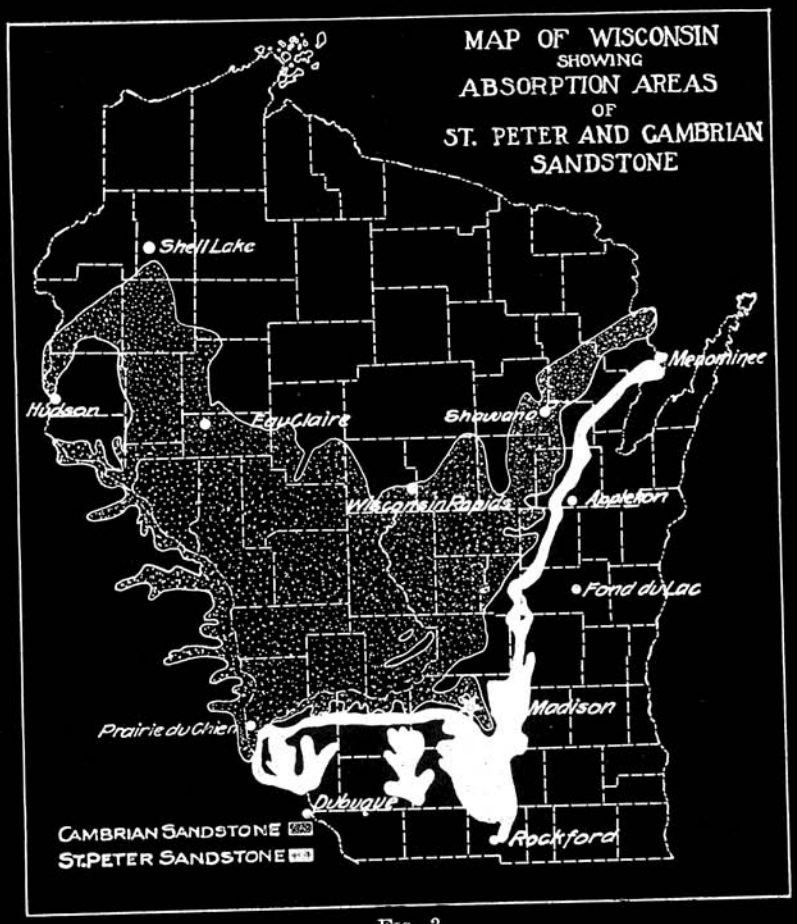

FIG. 3.

harder west of Rockford than east, just the reverse is true with the Mt. Simon water, which is softer, has less residue, and is lower in carbonate west of Rockford than east.

In making comparisons of analyses of waters from wells penetrating the three sandstones, considered in order from north to south, a marked increase in mineralization was found which not only makes these waters

undesirable from an industrial standpoint but frequently imparts a most unpleasant taste.

These, then, are the general facts in connection with the deep-well water situation. With few exceptions the hardness varies from 11 grains per gallon (190 p. p. m.) up to as high as 70 grains per gallon (1200 p. p. m.). A detailed comparison of analyses discloses localities where the waters have a strong odor and taste of sulfur, in others an oily taste, and in still others, particularly in the Mt. Simon at depths of 2,100 and more, strong salt brines are encountered.

A well recently drilled in Lake County for the Diamond Lake School yields a most unusual water. The hardness is only one-half grain per gallon (8.6 p. p. m.), but the mineral content is 1,909 p. p. m., consisting principally of 1,189 p. p. m. sodium carbonate, 319 p. p. m. sodium sulfate, and 379 p. p. m. sodium chloride. Truly a most unusual water, considering that the well is only 402 feet deep and the water likely comes from the lower part of the Niagaran Limestone.

Much has been accomplished in the study of water quality in this northern zone, but much as it is, it is only sufficient to point out the difficulties which are likely to be encountered and the great amount of work that must still be done before the yield and quality of well waters from the various aquifers can be predicted with reasonable assurance. The past and present methods of well construction are largely responsible for these difficulties and uncertainties, in that it is customary to leave open or uncased all those rock areas which will stand without caving. This practice permits an intermingling of the water from one aquifer with that of another and in addition permits water from one under a strong head, or pressure, to overcome a less pressure and flow outward from the well through other porous strata. Thus it may come about that an uncased well or an abandoned well where the casing has become porous through corrosion may be the source whereby a good vein of water of limited quantity in a well some distance away may be seriously affected by a strong vein of poor water. This rather serious condition is further aggravated by the practice of shooting in order to increase the yield. Shooting not only loosens the aquifers but it certainly must disturb and crack strata which otherwise may be tight, thus making it easy for the interchange as just mentioned. Shooting, further, is very likely to so disturb the casing as to forever prevent making it tight. The only justification that can ever be given for shooting is, "procuring a large yield," but there are so many detrimental effects that apparently it is a questionable, as well as an uneconomical, practice.

Since poor waters are in greater abundance than those of more desirable quality, there may be, as time goes on, a distinct lowering of quality which, in turn, will mean a greater expense to the house owner, to say nothing of the municipality and industrial plant.

Central Zone.

In the central zone, which is that portion of the state lying between the Onarga, Fairbury, Elmwood, Stronghurst line and a line across the state approximately through the cities of Casey, Neoga, Nokomis, and Carlinville, the water supply situation is more complex. In this area such water supplies as are obtained from wells must come from the "drift," deposits of sand, gravel, and clay, debris from the glacial invasion. Deposited as it was, there is no uniformity in the drift, and the location of a successful well is partly luck. However, these glacial deposits have been studied, their limits and contents investigated to such an extent that the matter of guess or luck can be reduced to a small margin.

The Wisconsin Glacier extended over the northern zone as far west as the eastern portion of the Rock River valley and across the Illinois River valley at Peoria, spreading out over the southeastern portion of the northern zone and over that portion of the central zone east of the Illinois River. Wells in this area seldom exceed 300 feet in depth, and the water is obtained from the sand and gravel reservoirs left by the receding ice sheet, the replenishment of which must come in a large measure directly from what may be termed local precipitation.

The size of the gravel and sand grains of this drift vary greatly, but in the main they are small, of many kinds of material, and in the aggregate they present a vast surface for a solvent reaction by the percolating water. Hence, it is not surprising to find that the water supplies in this zone vary greatly in character and volume, being usually inadequate in quantity and highly mineralized and hard as to quality. Drift-well waters in this area with few exceptions contain iron in such quantities as to stain white plumbing fixtures as well as causing incrustation in the water mains, thus reducing their carrying capacities. Iron is further objectionable since it stimulates the growth of crenothrix bacteria which, upon dying, decompose and give a very unpleasant smell and taste to the water. An iron-removal plant is a necessity with a water having an iron content in excess of 0.2 p. p. m. It is from this central zone that requests for information regarding a new supply or the improvement of the quality of an existing one are most frequently received.

A study of a map whereon have been shown the various municipalities and the kind of water supply in each is most impressive as tending

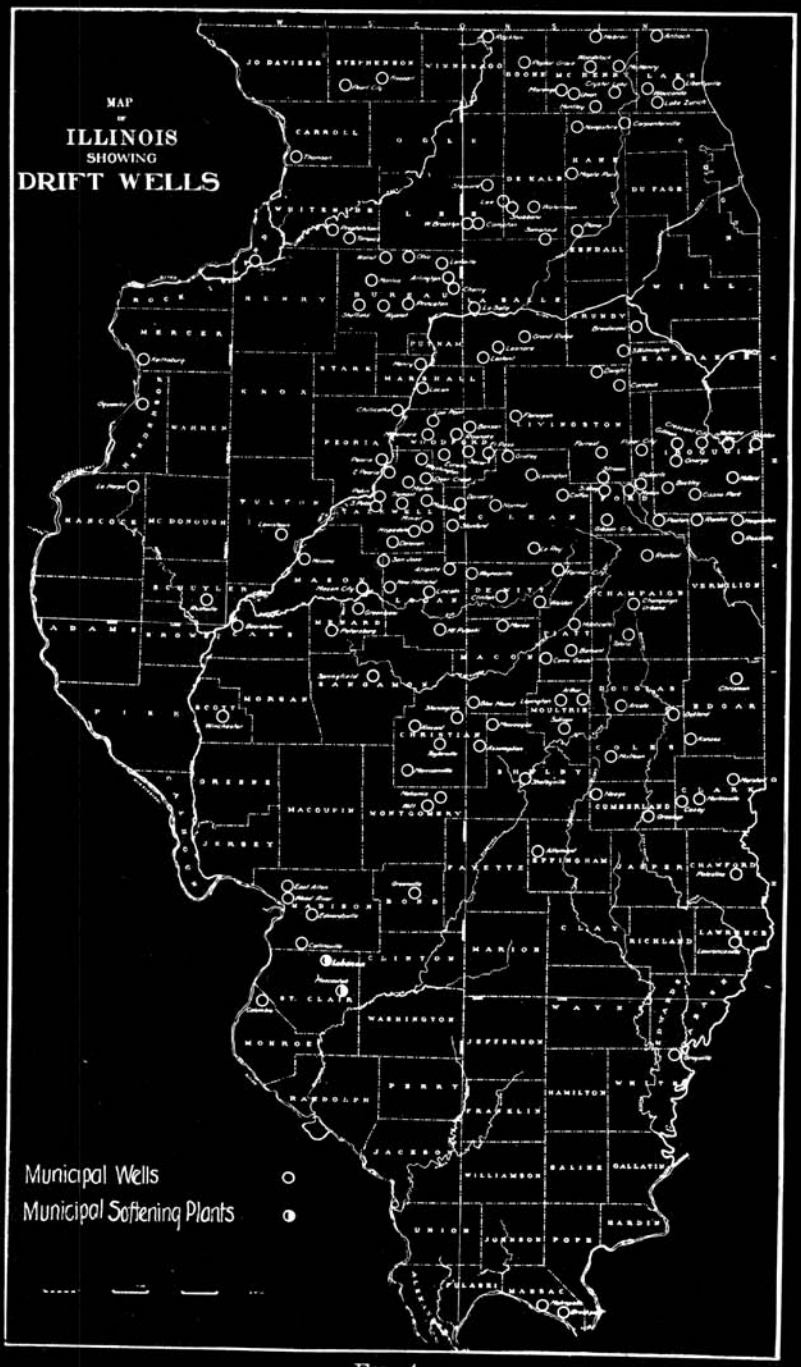
MAP
OF
ILLINOIS
SHOWING
DRIFT WELLS
Municipal Wells
Municipal Softening Plants

FIG. 4.

strongly to indicate that municipalities with adequate quantities of soft water are growing more rapidly than those equally well located, otherwise, but whose water supplies are not attractive to industrial expansion. These facts have been so well brought out that Springfield has installed a modern filtration and water-softening plant and Bloomington, which for years plodded along with a well water of 800 p. p. m. hardness, has recently finished the construction of a surface impounding reservoir and an up-to-the-minute filtration and softening plant, which is now delivering to the city a water with a hardness of only 100 p. p. m.

Southern Zone.

The southern zone comprises all that portion of Illinois lying south of the Casey, Neoga, Nokomis, Carlinville line. This is an area wherein practically all municipal supplies are obtained from streams or impounding reservoirs and are rendered pure and wholesome by treatment in a filtration plant. The Ozark uplift traverses the southern part of this zone and produces a geological confusion to the extent that at Anna, Mounds, and Mound City water from rock wells is obtainable. This water is not excessively hard, though at Mounds and Mound City it does contain objectionable amounts of iron. Water from the few other rock wells in this area is generally hard and highly mineralized, so that it is objectionable for many purposes. In addition, there are some five or six municipalities which secure a fairly acceptable supply from drift deposits.

Present Tendencies.

This, in brief, is the situation with regard to public and industrial water supplies in Illinois, and it is a problem which should be studied carefully by all those who have at heart the future welfare of their home towns and the state. Well-water supplies for many municipalities and industries are in serious danger of depletion, largely through carelessness in construction, use, and maintenance.

In the northern zone the increasingly heavy draft upon the rock wells is steadily lowering the pumping levels, thus adding a gradually increasing burden of pumping costs. This recession is taking place at a rate estimated at from 5 to 8 feet per year and has already reached such serious proportions in the metropolitan area of Chicago that the question of supplying filtered lake water to the municipalities and industries within a radius of 20 or more miles of the lake shore is being seriously proposed by well-informed engineers.

In former years the yield from the St. Peter sandstone was sufficient for all demands in such cities as Rockford but so many wells have been

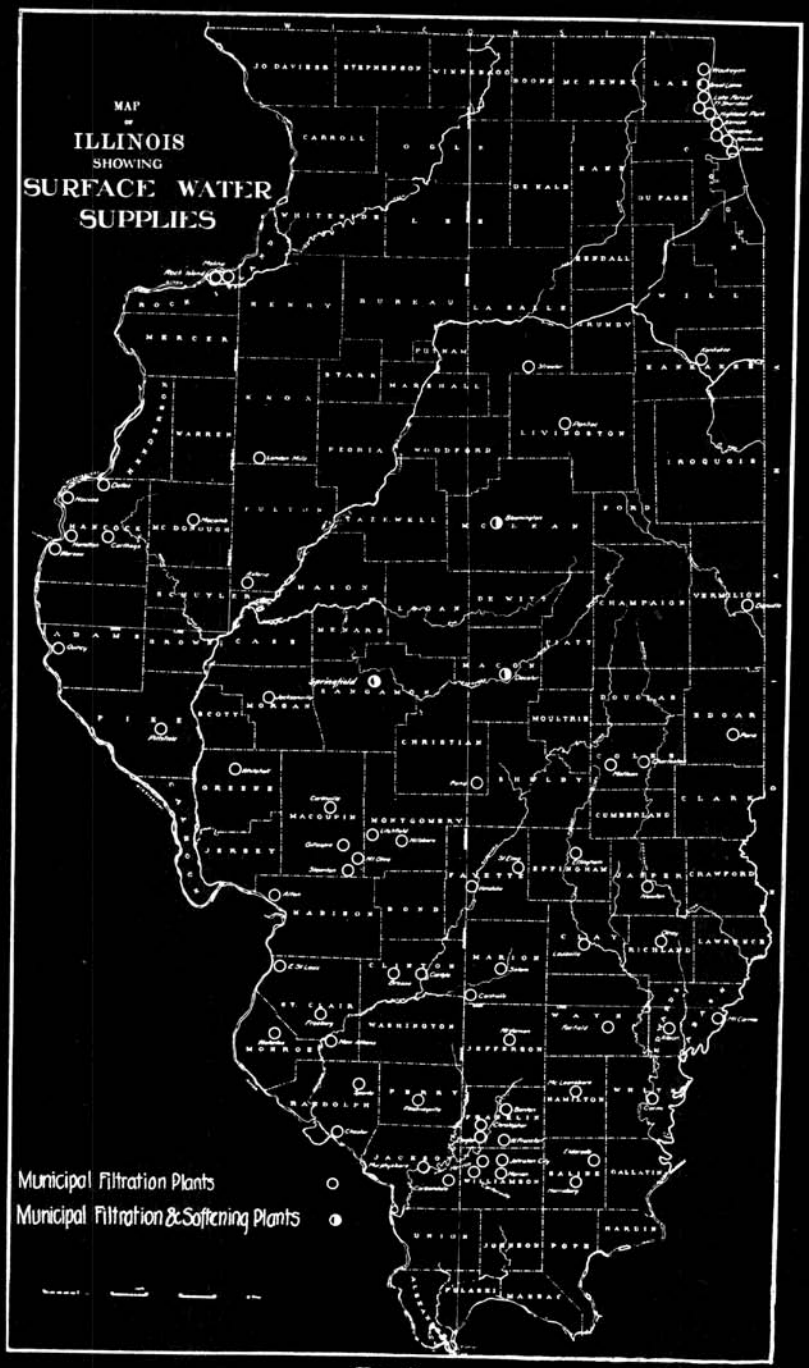
MAP
OF
ILLINOIS
SHOWING
SURFACE WATER
SUPPLIES
Municipal Filtration Plants
Municipal Filtration & Softening Plants

FIG. 5.

drilled into the formation that in many places it is now practically dry. A recently drilled well near Barrington produced less than 20 gallons per minute, while a new well at Crystal Lake gave practically no water from the sandstone. Specifications calling for wells that will produce 1,000 to 1,500 gallons per minute are being prepared at frequent intervals, and wells to deliver this great volume of water must penetrate as deeply as is possible, passing through all aquifers without entering areas of bad water. Even though such wells yield a high quality of fresh water during their early life, there is grave danger that with the lowering of the water level in the general vicinity of the well the hydraulic equilibrium will be unbalanced and water of inferior quality will be forced into the well from lower depths.

Not only are the water levels in wells in both the the northern and central zones, receding, causing the construction of new and larger wells, but analytical data indicate that the heavy pumping drafts are bringing about a detrimental change in water quality. Particularly is this true in the central zone, where water is obtained from drift wells.

That Illinois is richly blessed in the matter of water supply, as compared to some other states, is strikingly illustrated by the great sums spent by certain cities for adequate water supplies. An excellent example is the City of Los Angeles. When the Owens River project was constructed, it was felt by many people that the water problem had been solved for practically all time, and the building of a water supply conduit some 200 miles or more in length was hailed as a great engineering achievement. Now the city authorities are planning to take water from the Colorado River at a site called Boulder Dam, some 280 miles away. It will also be necessary to raise the water higher than a quarter mile in order to pass over a low mountain range near the river. Such is the priceless value of water.

Summary

In conclusion, it seems desirable to summarize the situation and to offer some lines of thought as the first steps in building up a keener appreciation of the water problems in Illinois:

1. The state has three zones, in each of which water is obtained (as a general proposition) in a different way or from a different source.
2. In the north zone, wells are usually drilled into the rock and may vary in depth from 100 feet to over 2,000 feet.
3. The quality of water from rock wells differs considerably in the different aquifers and also varies in each aquifer in accordance with its position. The farther south and, hence, the deeper the penetration to any aquifer, the more highly mineralized and less desirable the water becomes.

The approximate southern limit for usable water is reached at a line through Onarga, Fairbury, Elmwood, and Stronghurst.

4. Marked changes in the character of water from the same formation are found on east-and-west lines across the state as well as from north to south.

5. Deformation of the earth's crust during early geological periods has introduced conditions which are apparently responsible for local variations in water quality of a marked character within very narrow limits of area.

6. Under present methods of construction, uncased bores permit commingling of waters from several aquifers and a consequent lowering in quality for the sake of quantity.

7. The practice of shooting a well to increase its yield unquestionably affects the condition of all the aquifers in the vicinity of the well and may easily cause damage to a well some distance away through admission of undesirable water to an otherwise desirable underground source.

8. The necessity of keeping the yield of rock wells in step with the increasing demands of a prosperous and growing community results in the lowering of pumping levels and increases the cost of production, which ultimately may bring about the abandonment of the well.

9. Excessive pumping may cause a change in the quality of water obtained from a well.

10. In the central zone, wells are comparatively shallow and water is usually high mineralized, particularly with iron.

11. There is no order in the wide variation in the quality of water from drift wells.

12. There is a limit to the yield of drift wells, and when they are pumped excessively a marked increase in mineral content has frequently been noted.

13. On account of the irregularity of the drift deposits, the work of locating a water supply is rendered much more difficult and expensive.

14. In the southern zone, water supplies are largely obtained from streams or artificial impounding reservoirs.

15. Surface-water supplies are made satisfactory by treatment in a modern filtration plant.

16. High-grade water, low in mineral content, is cheap at any price to the individual, the municipality, or the industry and is essential to the growth and prosperity of all.

From this review it is evident that research studies into the matter of the water resources for municipal and industrial supplies is an activity of great value to the state and its citizens; that the amount of present information is but a small percentage of that which should be available; and that the value of certain data is directly related to the frequency with which it is used. Therefore, to realize the greatest benefit from these investigations, the knowledge that such information is obtainable and the benefits that may be derived from its use should be known by all.

Organizations of the character of the State Academy of Science are ideal for presentation of these data, as the minds of the membership are highly receptive to the importance and value of such scientific information. However, this is not a treasure to be hidden like a pirate's chest, but on the contrary is of greatest benefit when it has reached the point of being common knowledge. The education of the people of the state to a realization of the economic importance of water quality may take time, but it is through the trained mind that such is accomplished. The State Water Survey and the State Geological Survey are deeply appreciative of the interest and support that has already been given to their work, but it is sincerely desired that there be created a more wide-spread appreciation of the value of research investigations of the resources and quality of water supplies, especially from wells, by the citizens of the state at large, for the support of a program of more intensive studies, to the end that knowledge as to the yield and quality of water supplies may be available for any locality. If the continued prosperity of the state is to be maintained, this program must be placed in operation now in anticipation of the requirements of ten or twenty years in the future. For the evidence indicates that the value of soft water is gaining converts at an increasingly rapid rate each year.