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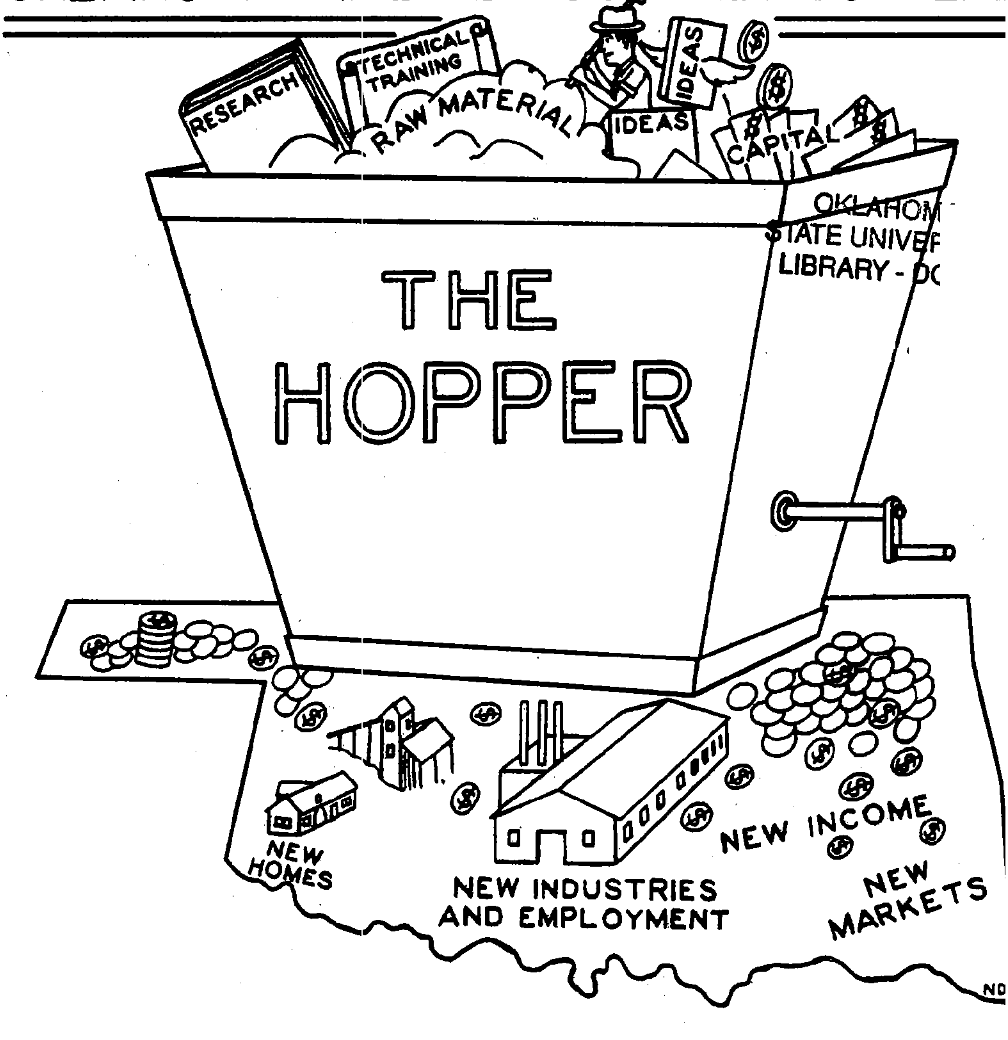

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ARTIFICIAL RECHARGE OF GROUND WATER RESERVOIRS

by
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(Paper presented at Second Oklahoma Water Well
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Artificial recharge of ground water reservoirs from surface water is simply a way of assisting nature in the storage of water against the day when nature withholds its rains. This method of recharge reveals very little that is not already practiced by nature. Thus artificial recharge serves as nature's partner in providing more ground water for our industry, cities, towns and agriculture.

All our lives we have observed the influence of rainfall, rivers and lakes on the natural recharge of ground water supplies. Ground water levels are often lowered and storage greatly depleted, largely due to deficiencies in rainfall and natural inflow or the withdrawal of water in excell of natural recharge.

The need for more potable water has resulted in the use of artificial recharge in a good many places over the United States, with increasingly good results. After widespread inquiry, I have been unable to find an example of artificial recharge practice in Oklahoma insofar as fresh water is concerned. There are a number of locations in the State where a thorough investigation should be made for possible beneficial use.

The oil and gas industry in Oklahoma and elsewhere is using artificial recharge for the sub-surface storage of oil field brine, natural gas, and the flooding of oil formations to increase recovery of oil.

In our state we are witnessing an unusual increase in the demand for water. Industry, cities and towns are all growing--each needing more water. Most cities in our state use a large volume of water and are dependent upon surface reservoirs. Oklahoma City, for example, is consuming 80 percent more water than we used in 1940. This year Oklahoma City will use about eight billion gallons of water. Minimum day in the winter months, 20 million gallons; maximum day in the summer, 45 million gallons.

The ground water around Oklahoma City has been carefully investigated. We have watched the lowering of the ground water level in the Garber Sandstone since 1936, the year of maximum withdrawal, estimated to be 10 mgd - much less now.

The shales above the Garber have low permeability, small production, and highly mineralized water.

The alluvium of the North Canadian River has been used for emergencies by the Oklahoma City Water Department. We have produced up to 4 mgd. This water is highly mineralized--about 24 grains total hardness.

The natural recharge of this reservoir is from rainfall and the North Canadian River. Slope of the alluvium averages 5 feet per mile of river. Voids in the sand total about 40 percent. Natural flow in the fine sand is 6 inches per day, and in coarse sand where wells are located 1-1/2 to 2 feet per day, based on tests made at a number of places over a period of years. The withdrawal of water from this formation is dewatering when high rates are used--for example, 100 to 200 gpm with well spacing of 800 to 1,000 feet. For your information this formation below Oklahoma City for several miles has been ruined since salt water from oil production has been discharged in the North Canadian River east of the City. Recent tests of this ground water at East 4th Street and Grand Boulevard show high Chloride content, up to 7,350 ppm.

Although we have two surface reservoirs with a total capacity of 95,000 acre feet of water, we will maintain an active interest in sub-surface reservoirs for any new development and possible future use. However, there are hundreds of industries, towns, and individual users which are dependent upon ground water as the only supply economically feasible. We must therefore make the maximum beneficial use of our ground water reservoir.

Artificial recharge is not feasible everywhere, nor is it necessary or practical in other places. However, in those areas where the ground water supply is inadequate, a thorough investigation will determine the possibility of inducing recharge from surface water to ground water formations. The success of this method to increase available ground water is dependent on information involving the application of both geology and engineering, and large amounts of common sense. Investigation of local geology is necessary to determine the nature of sub-surface reservoirs, their capacity for storage of water, and their ability to yield as well as receive water. Also, the quality and quantity of surface water available for use, and method of recharge to be used, the design and spacing of wells, and the observation and records of the harvest of water should be determined. These and many other factors are of tremendous importance to determine the success of artificial recharge.

Here are a few examples where artificial recharge is being practiced with increasingly good results. Long Island, which is a part of New York City, records one of the first examples of ground water conservation by returning water to the ground. Harry H. Johnson presented a review of the results at the American Water Works Association Conference at Atlantic City, New Jersey, May 4th, 1948. Mr.

Johnson reported that uncontrolled water well drilling increased year after year in this industrialized area, resulting in the lowering of the water table and the salting of many large private and public water supply wells. This resulted in 1932 of a joint investigation by the New York Water Service Corporation, the City of New York, and the Jamaica Water Supply Company making a study of existing ground water levels in Kings County. Prior to 1933, the use of wells as a means of returning water into the ground had been but little employed.

On April 28, 1933, the Conservation Law was passed by the New York State Legislature, placing the ground water of Long Island under the jurisdiction of the Water Power and Control Commission. Since that time the Commission has prohibited the drilling of new industrial wells with capacities in excess of 69.4 gpm (100,000 gpd), unless the water pumped is returned in an uncontaminated condition into the ground through recharge wells or other approved structures.

Recharge wells include a variety of types. The most common type used in Long Island is 24 to 48 inches outside diameter with a 6 to 12-inch inside casing, gravel packed.

It is interesting to note the drillers, geologists, engineers, and other interested parties got together and drew up a set of specifications which were thereafter taken into consideration when applications for approval of recharge well projects were submitted to the Commission.

Ground water levels have been stabilized. There is one phase of the problem, however, which is progressively getting worse and may ultimately change the present concept of diffusion. This is the rise in temperature of the ground water itself, when used for cooling.

Also, there are now over 300 recharge wells on Long Island, many of which are capable of returning as much as 1,000 gpm to the ground reservoir. The total water returned to the ground formation amounts to about 60 mgd.

"Good to the last drop" is the water supply of Newark, New Jersey---at least the City Water Engineers have come up with a means of using it all to good advantage. The American Water Works Association Journal reports that Newark has an available supply of 100 mgd stored in the two surface reservoirs, and drew on its storage to the tune of 81 mgd during the past year. Meanwhile the rapid expansion of industry took a record industrial supply out of its own wells, lowering ground water levels in the area to a point where the wells began to yield brackish water.

The ingenious solution now under experiment involves the diversion of overflow from the Pequannock Reservoir into wells to recharge the depleted ground water pool. In a recent test the Water Works returned 200 million gallons of overflow water to the ground. Investigations continue to determine whether the program will be effective in the long run and whether it will be worth $3.00 per million gallons to "plant" the water underground. Indications are most encouraging. Depletion has been halted in the water levels, down 100 feet in the past 25 years.

Infiltration galleries from which the public water supply of Des Moines, Iowa, is obtained, are recharged artificially from shallow basins excavated over the galleries. Similar projects are in operation at other places in the eastern part of the United States, including Dayton, Ohio. Recharge from an artificial lake is accomplished in the Duhernal Water Supply Development near Old Bridge, New Jersey.

During the War, Louisville, Kentucky, pumpage of ground water exceeded the recharge and ground water levels declined. Artificial recharge of certain wells was undertaken at the suggestion of the U.S.G.S. War Production Board, and industries concerned. This artificial recharge permitted continued production by industry, whose production otherwise would have had to be curtailed for lack of water.

Similar artificial recharge by wells is used in Indianapolis, Indiana, and several places in Virginia. This recharge is practiced with cold filtered surface water in the winter, where value of ground water for cooling purposes make this practice economically feasible. Water must be free of silt, and chemical characteristics must be suitable when surface water is used in recharge wells.

In Los Angeles County, California, dry stream beds are deeply scarified to break up the dry silt crust, so flows of water in the river, when they occur, will recharge the ground water reservoirs more quickly. Also, this method is extensively used in Arizona and New Mexico. In some of these areas, submerged clay dams are constructed in the sandy river bed to retain more water for recharging the ground water reservoirs located in the valley of the water course.

In Ohio, rock cribs and gravel filters are placed in the river bed to provide more water for recharging the ground water supply. Flows of water in the river remove the silt deposited on filters. In some places these filters are located over infiltration galleries constructed under the river channel, providing more water from stream flow and less withdrawal from ground water reservoirs. Infiltration from streams below dams is another illustration. Such artificial recharge and use of river water for domestic purposes and for industry is dependent upon a suitable quality of surface water.

A review of the methods gives us illustration of the use of recharge wells, infiltration galleries, rock cribs, gravel filters, submerged clay dams, flooding and use of streams and surface reservoirs utilized in the artificial recharge of ground water reservoirs.

Conclusions: Fortunately in some places natural recharge is large and therefore presents no problem at this time. On the other hand, in other areas heavy withdrawals from wells are depleting the ground water supply and cannot be continued indefinitely. We have briefly reviewed the experience of several places over the country which are successfully using artificial recharge methods to assist nature in supplying ground water.

It appears likely that there are places in Oklahoma where we could use artificial recharge to supplement the ground water supply.

The successful application and use of artificial recharge in connection with conservation and development of ground water supplies is dependent upon thorough investigations, records, effective control of withdrawals as well as recharge, and we must continue to practice protection to public health.

It is encouraging to see more and more an exchange of experience on this subject. This meeting of the Well Drillers is a good example. You are to be commended on your active interest, as well as other interested parties, such as the engineers, geologists, and public officials. In this way you are making important contributions to the advancement of the science of ground water development. We must continue to pool our surveys, investigations, and records. We will all benefit with this information. An adequate supply of water means more business, more prosperous active cities, towns, industry, and agriculture in our state.

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MINERAL FUELS TURN THE WHEELS;
AND OKLAHOMA HAS ALL THREE

Importance of the mineral fuels to American economy is convincingly brought out in a recent paper entitled "Multiple Fuel Needs of the American Economy", by Walter H. Voskuil, mineral economist of the Illinois Geological Survey, when he points out that the United States uses fuel and power equivalent to about one billion tons of coal each year. This tremendous amount of energy comes mostly from four sources--coal, petroleum, natural gas, and water power--computed to equivalent tons of coal. Wood is important as a source of domestic fuel in many areas but is no longer an important factor for industrial or commercial sources of heat and energy.

Use of mineral fuels in the United States thus averages about the equivalent of 7 tons of coal per capita each year. The distribution and reserves of coal and lignite are believed to be pretty well known, and rates of production tend to adjust to changes in demand. However, the diversity and flexibility of American industry with its adaptation of mechanical power to an ever increasing number of applications calls for many special types of fuel. To meet all the requirements of American industry and commerce, large quantities of each type of mineral fuel must be constantly available. Because a large part of the fuel energy of this country is supplied from petroleum and natural gas, and because the reserves of these materials are less obvious than those of coal, an important task of the American petroleum industry is constant exploration for new reserves.

Referring to the importance of special fuels for particular porposes, Voskuil states: "The beginning of our modern industrial economy and its growth rested on several specially prepared fuels that permit no substitution. The number of specially prepared fuels tends to increase because they do their work with increasing efficiency. ...the very fact that we have ample supplies of solid, liquid, and gaseous fuels at low cost provides an opportunity for the development of power-using activities that would be out of the question if our fuel supply were limited to coal alone."

Comparative costs influence the choice of fuels in many industrial and commercial uses of fuel, as well as in the domestic market. However, there are many requirements for special types of fuels in which substitution of other types is not practical. In a paper entitled "Economic factors involved in selection of boilers for process steam and power generation", by W. S. Patterson and R. L. Ricker of New York, presented before the regional meeting of the American Institute of Chemical Engineers at Tulsa in May, comparative costs of the three basic fuels, oil, natural gas, and coal, were given. The figures used by Patterson and Ricker, which gave natural gas an advantage in cost for heat, are as follows: Natural gas having 1000 Btu per M. cu. ft., costing 22.5¢ per M cu. ft. and at 70 percent efficiency, is comparable to oil, having 18,500 Btu per pound at 3.63¢ per gallon and at 75 percent efficiency, and coal having 13,500 Btu per pound at $7.00 per ton and at 80 percent efficiency. The cost prices would differ in Oklahoma, where all three fuels are abundant. For example, where natural gas can be obtained at 15¢ a thousand cubic feet, the cost for one million Btu would be 15¢, or less than half the 22.5 cents given by Patterson and Ricker.

Although there may be numerous uses of specially prepared fuels for which there can be no substitution, it does not necessarily follow that there will not be competition for these special fuel markets. There can be competition among producers as to which type of mineral fuel is used by the processor to make the specialized fuels. Although oil and natural gas have made serious inroads into fuel markets formerly supplied by coal, for example, railroad fuel and power generation, research on hydrogenation of coal indicates a possibility that coal may become a competitor of oil as a source material for liquid fuels and liquid fuels from natural gas are in the offing. Thus, the expanding field of fuel research is playing a part not only in the present positions of the various mineral fuels, but of equal or greater importance in developing new lines of competition that will tend to insure American industry the best fuels at lowest cost in the years ahead.

Fuel for heat and power is an essential for any industrial development, and Oklahoma's ability to supply fuel has been referred to many times. This is one subject about which Oklahomans can do much talking, and remain neutral. Just keep repeating that whether it is natural gas, crude oil, coal, or liquefied petroleum gases that is wanted, it can be obtained in Oklahoma. Yes, when it comes to fuel, we have it—and at comparatively low cost.