ARTIFICIAL GROUND WATER RECHARGE AT PEORIA, ILLINOIS

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In Peoria, Illinois, ground water is obtained from glacial drift deposits varying from 10 to 200 feet in depth. In addition to municipal use, most industries also pump this water. In 1940 it was found by the State Water Survey that ground-water levels were dropping about two feet per year and that the cause was over-pumpage. It was also found that the river does not contribute to the ground-water storage when it is at pool level and only very little when in flood stages.

To reduce lowering of ground-water levels, two principles can be used: a) pump less water; or b) increase the recharge of ground-water storage. Both methods have been used. Once informed about the causes of the lowering, industry cooperated by reducing its pumpage to the extent of 15 million gallons per day mainly by using river water for condensers or by building cooling towers. These measures reduced the recession of water tables to about 0.6 foot per year.

A trial of artificial recharge was made in 1941 in an old gravel pit on the property of Hiram Walker & Sons, and it was found that recharge could be made at a rate corresponding to the height of a water column of 111 feet per day over the water surface or at rate of 37 million gallons per day per acre.

Artificial recharge can be obtained in several ways. In Peoria we studied the use of land flooding, pits, and wells.

Land-flooding, as a rule, gives rates of inflow from a few inches to a maximum of five feet. Inasmuch as in Peoria the over-pumpage was calculated to be 8 to 10 million gallons per day we would need 30 acres to flood if the rate of inflow averaged one foot per day. This amount of free land was not available in the industrial area where the recharge was needed.

It was, therefore, considered necessary to find a method which allowed a high rate of recharge over a small area. Wells or pits can be used for this purpose. Wells require clean water or they clog and are difficult to put back in operation. The cost of a filter plant and recharge wells was estimated to be about $5 million whereas the cost of a pit was approximately $100,000. From this standpoint it was not difficult to choose.

The quality of the river water was found to be satisfactory for infiltration; it had a turbidity of less than 100 p.p.m. for 300 days per year and a normal bacterial count of 26,000 per ml. However, convincing people locally that river water can be used for recharge required much time and effort.

The State of Illinois appropriated funds that would have allowed the construction of a small recharge test-pit with a capacity of about

300,000 gallons per day. The Peoria industries, being interested in getting even more water into the ground, raised an additional $70,000 to enable construction of a larger pit having a possible capacity of one million gallons per day over the year, that is, two million gallons per day over the approximate six-month operating period. The pit is operated only during the winter period when the river water is below 65°F. The contribution from the industries, fortunately, was made with a free rein for research, and there was never any pressure exercised merely to get more water into the ground. The water committee of the Peoria Association of Commerce always considered the work as a research project designed and operated to find ways to solve the problem of rapid recharge.

Description

The installation is relatively simple. River water passes through a coarse screen to a so-called control tower, where it is chlorinated, measured, and passed through fine screens with ⅛-inch slots. It then enters the pit which has its bottom 10 feet below pool stage of the river and thus is charged by gravity flow. To protect the natural ground from settling the pit was lined with a six-inch layer of filtering material.

In 1956 a second recharge pit, with some modifications in shape, was built near the first one. The water is pumped into this no. 2 pit.

Whereas pit 1 has a bottom 40 by 62.5 feet (2500 sq. ft.) with 1:2 slopes, pit no. 2 has a bottom of 20 by 75 feet (1500 sq. ft.) with 1:3 slopes.

Industrial Pits

The pit belonging to the Bemis Brothers Bag Company in Peoria, which has a bottom only 10 by 50 feet and slopes of 1:3, was built with advice of the Water Survey.

In contrast the Peoria Water Works Company built a pit with a bottom 350 by 200 feet and 1:3 slopes with a six-inch layer of sand as filter.

There are in Peoria, therefore, four pits of various shapes available for observation and comparative study.

Rates of Inflow

It is interesting to compare the average rates of inflow in feet per day in these pits.

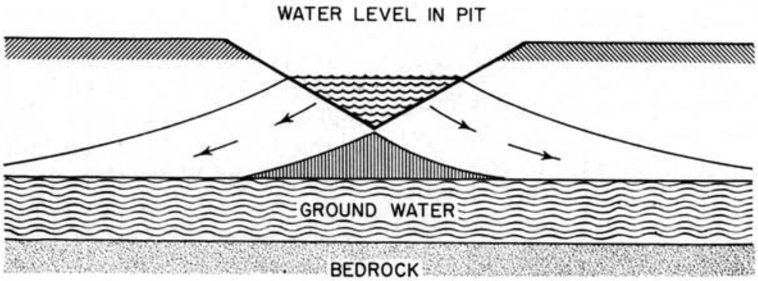
Pit 1	60
Pit 2	120
Bemis Bag Co. pit	200
Water Works Co. pit	8

The Peoria Water Works Company pit approaches land-flooding types of recharge in size and recharge rate.

The high recharge rate of the other pits, however, is surpising and exceeds the rate of any known pit. The reasons for this high rate are well worth discussing, as the design of many pits seems to overlook some fundamental reasoning.

Design Factors

In any recharge pit, the water level in the pit must be above the original ground-water level in order to have some head to produce flow. The volume of soil between the pit and the ground water is soon saturated with water. In Peoria we calculate that this happens in three hours.



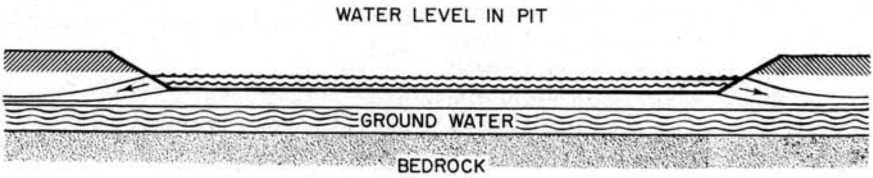


Fig. 1.—Sections through pits and flow diagram; *above*, Pit without bottom, only slopes; *below*, Pit with large bottom.

Any additional water can flow from the pit only if it can flow from the pit laterally. The water flowing through the sides of the pit has a free direct path for this lateral flow. The water flowing through the bottom has to squeeze through underneath the flow from the sides, and in large bottoms the flow from one part of the bottom can block or hold back flow from another part. It thus becomes evident that large bottoms are of no great help in increasing the rate of inflow.

Assuming a pit without a bottom (Fig. 1, above), there is flow only through the sides, and beneath its lowest point is a sector with no flow, as stream lines cannot cross themself.

In a pit with a very large bottom (Fig. 1, below), it can be seen that a limited lateral flow is possible only through a section along the edge of the bottom. In large pits this may be less than could flow through the bottom due to its permeability. This accounts for the low rate of inflow in land-flooding operations.

The geometrical shape of the pit is therefore of great importance in obtaining a high rate of inflow.

It was also found that a high percentage of the wet area should be in the slopes (Fig. 2). At operating levels in the pits in Peoria, this area amounts to:

Pit 1	55 percent
Pit 2	75
Bemis Bag Co.	90
Water Works Co.	20

Filter Material

Another rather unexpected factor in obtaining and maintaining high rates of infiltration was the filter material.

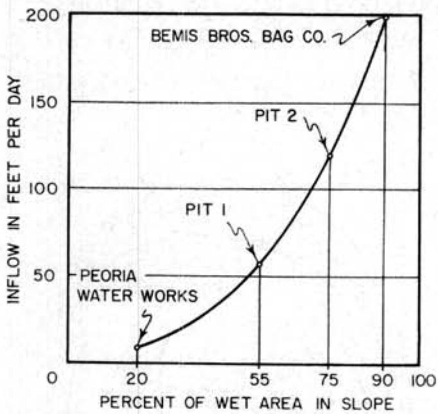


FIG. 2.—Relation between inflow and percent of wet area in slope.

For the first three years sand of one-millimeter size was used for filtering. This sand clogged rapidly and at the end of a winter season the capacity of the pit was reduced 40 to 60%. Then, in a bold step, ⅜-inch gravel was used as filter material. This material was predicted as not being capable of acting as a filter, but in our testing it proved effective.

A silt film developed rapidly over the gravel and the top gravel collected more silt than the lower layers. At the end of the season practically all of the silt introduced into the pit by the river water could be accounted for in the top layer of gravel. What was even more important, the initial inflow was about 5% higher than with sand as a filter and the reduction during a winter season amounted to only 12 to 15%. This solved to a great extent the constancy of the pit operation.

During 1957-58 pits nos. 1 and 2 were operated without previous cleaning. So far the loss in the recharge rate is only 4% compared to the previous year. This low loss of capacity suggests that operation of the pits may be possible three years without cleaning.

It is our opinion that use of pea gravel as a filtering material, geometric shape of the pit, and flow through the sides are the main factors in the high rate of recharge of the pits in Peoria. However, many other factors also enter the problem of ground-water recharge.

CONCLUSIONS

Technically, we found a way to produce a high rate of recharge of water into the earth. On the other hand we do not yet know why many of the methods work. We do not know the most favorable geometric shape for a pit or the proportions of sides, bottom, and slopes. We do not know why pea gravel actually filters or the limit of coarseness of material that could be used. However, theoretical and experimental studies on these explanations are underway.

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