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The Relation of River Stages to Ground-Water Levels at Pittsburgh, Pa.[1]

By D. W. Van Tuyl
(Engineer, Pittsburgh, Pa., G.W.)

The Ohio River is formed by the confluence of the Allegheny and Monongahela Rivers at the point of the "Golden Triangle" in Pittsburgh. All three streams are controlled by series of low dams which are traversed by ships through systems of locks. Except during periods of high runoff, the pools above the dams are maintained at relatively constant stages. The river level generally does not fall below the normal pool stages. This condition has an important bearing on ground-water levels in the adjacent alluvial deposits, from which large supplies of ground water are pumped in the Pittsburgh area. Maximum hydraulic gradients in the aquifers are limited by the available or maximum possible drawdown of water level in the operating wells. This determines the ultimate yield of a well or group of wells.

As the principal source of recharge to the wells, the rivers contribute a greater proportion of water at times of high runoff than during times of normal stage. They are above pool stage only for short periods of time, however, and the amount of recharge to the aquifers then depends mainly on the height of the river crest and the position of the water table.

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[1] Prepared as part of cooperative ground-water investigations in Pennsylvania by the U. S. Geological Survey and the Pennsylvania Topographic and Geologic Survey.

Nearly all substantial rises in the river produce rises in ground-water levels in the valley sediments. The relationship in the Triangle area is neither direct nor uniform, however, owing to local geologic and man-made conditions and to the existence of a permanent cone of depression. The principal geologic factor is the buried-valley feature, which limits the lateral extent of the aquifer. The man-made factor--sheet piling under the Allegheny River wall--has reduced the area available for infiltration of river water into the aquifer. The regional cone of depression, caused by many years of pumping, remains throughout the year, although ground-water levels fluctuate seasonally as much as 10 or 12 feet in some observation wells in the area.

The graph in figure 1 shows the relation of river rises to ground-water rises for 11 winter and spring river peaks. Each plotted point represents an average of the rises in the number of observation wells shown. These rises are the heights--determined from hydrographs covering several years of record--to which the water level was raised above assumed base elevations. The highest river stage during the period studied (1933-50) occurred in the St. Patrick's Day flood of March 18, 1936, when the lower parts of the Triangle area were under water. No attempt has been made to construct a curve through the plotted values, because most of the rises in ground-water levels are based on periodic measurements that may not represent the absolute maximums produced by the river rises. Nevertheless, some relationship--possibly linear--is apparent in the graph. Neglecting the highest point and those represented by only two observation wells, a straight line with slope of unity would nearly represent the average relationship.

It appears from figure 1 that the water table is raised to a height that is determined by the height of the river crest. This relationship probably holds for rises that occur in the period from late autumn to early spring, during which time the water table is near its seasonal high level. It probably does not apply to rises that occur in the late spring and summer, which is the period of heavy pumping for cooling and air conditioning. (The regional pumping rate during the cooling season is nearly double the rate during the winter period.) The magnitude of ground-water rises caused by individual floods depends to a large extent on the time of year and consequently on the position of the water table just prior to the rise and on the temperature of the water. 2/

A detailed comparison of rises is shown by the hydrographs in figure 2. For the major peak on December 4, 1950, the time lag was about 54 hours at well A-13, which is about 1,850 feet from the Allegheny River. The time lag for the secondary peak was about 41 hours. In wells closer to the river the time lag probably was much shorter than for well A-13.

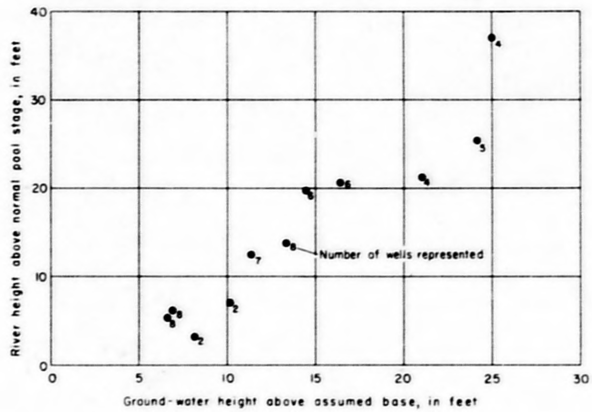
2/ Kazmann, R. G., River infiltration as a source of ground-water supply: Am. Soc. Civil Eng. Trans., Vol. 113, p. 404, June 1947.

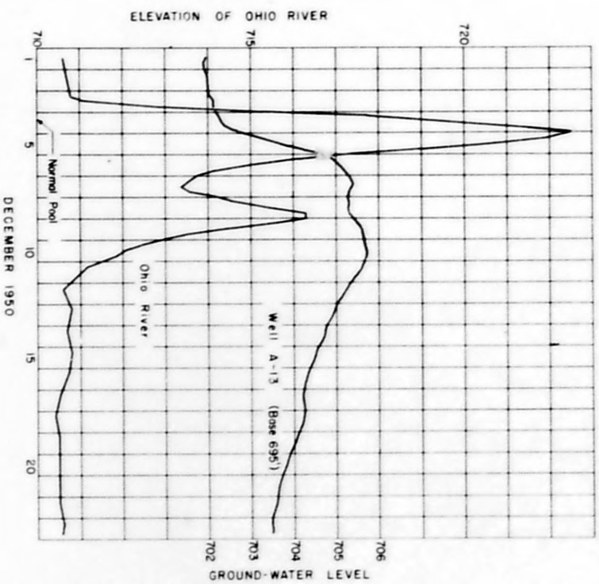
Determination of the exact time lag is not possible in other locations because measurements generally are made only weekly, whereas well A-13 is equipped with a recording gage.

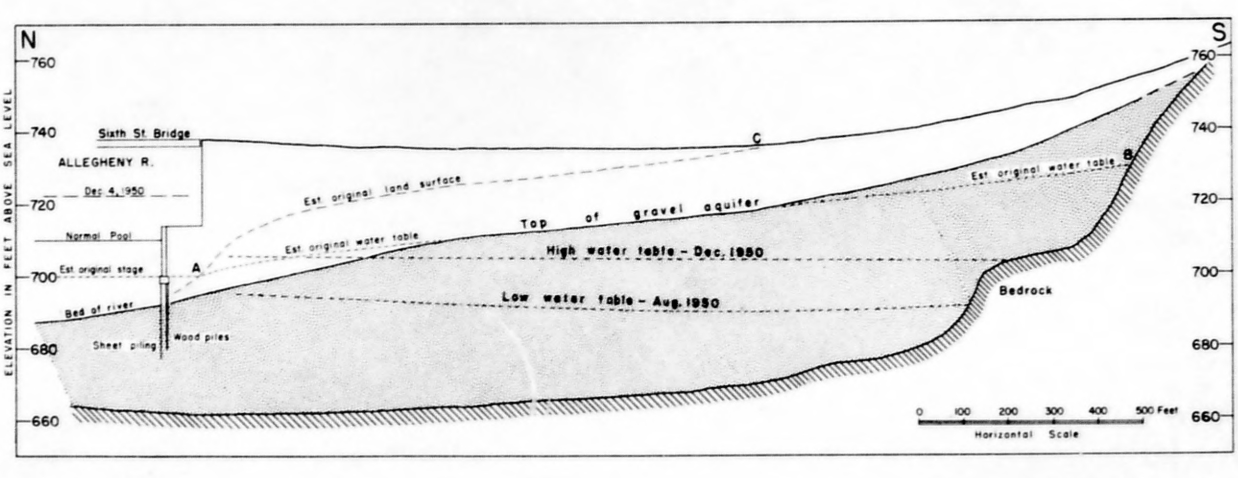
The cross section in figure 3 indicates in part the geology and hydrology of the Triangle area of Pittsburgh. Drawn across the center of the area and approximately at right angles to the Allegheny River, it shows the bedrock-valley wall, the thickness of the gravel aquifer, and position of the water table at two times during 1950. Also included are estimates of the original land-surface, water-table, and river elevation prior to the development of Pittsburgh. These estimates in part are speculation but do indicate the effects of man's occupation of the area. The drawing shows that development of the Triangle area has included encroachment on the Allegheny River and the placement of large volumes of fill above line AC in figure 3.

Assuming an original low-water stage in the Allegheny River of 700 feet, the former land and water surfaces may have intersected at point A in figure 3. This would indicate that the gravel aquifer was essentially full (to line AB) and that ground water was discharging into the river under a gradient of about 0.015 (15 feet per 1,000). The water table probably also sloped downstream, following more or less the natural slope of the river. The position of the water table in August 1950 represents in general the seasonal low resulting from heavy pumping for cooling and air conditioning. The seasonal high water table generally is 8 or 9 feet above the August position at this cross section. On the basis of the assumptions presented in figure 3, it appears that the original natural storage in the aquifer has been reduced nearly half in this part of the Triangle area. In addition, the slope of the water table has been reversed and recharge now is being induced from the river.

The effect of high river stage on the water table is shown in figure 3 by the relative position of each in December 1950. The river rose to elevation 722.5 feet and the water table to approximately 704 or 705 feet. At this time the river was 12.5 feet above normal pool (710 feet), and the water table was about this same amount higher than the August level. However, only part of the ground-water rise was caused by the change in river stage, as a recovery at approximately 8 feet had already occurred, owing to the seasonal reduction in pumping.


River height above normal pool stage, in feet
Ground-water height above assumed base, in feet
Number of wells represented
0
10
20
30
40
5
15
25


ELEVATION OF OHIO RIVER
710
715
720
DECEMBER 1950
Normal Pool
Ohio River
Well A-13 (Base 695')
GROUND-WATER LEVEL
702
703
704
705
706


N
S
ELEVATION IN FEET ABOVE SEA LEVEL
760
740
720
700
680
660
Sixth St. Bridge
ALLEGHENY R.
Dec 4, 1950
Normal Pool
Est original stage
Bed of river
Sheet piling
Wood piles
A
B
C
Est. original land surface
Est. original water table
Top of gravel aquifer
High water table - Dec. 1950
Low water table - Aug. 1950
Bedrock
0 100 200 300 400 500 Feet
Horizontal Scale