Agricultural Ground Water in Pingtung Plain of Taiwan

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The agricultural ground water in Pingtung Plain was investigated in 1969 at the request of Taiwan. The tritium of the sample water was sent to Japan later to our laboratory. On the basis of these results, a general survey on the ground water flow and on the relation between the ground water recharge and its utilization in Pingtung Plain was undertaken.

Ground water utilization and hydrogeology in Pingtung Plain

Pingtung Plain is situated in the southern region of Taiwan, extending over an area of 1,210 km^2. It lies in the subtropical zone climatically with the yearly average precipitation of 2,200 mm, 87 per cent of which falls in summer from May to October and the dry season comes in winter.

The eastern and northern Pingtung Plain areas are surrounded by the central mountains forming an alluvial cone of which the border parts are found with the consolidated terrace of diluvium gravel. In some seaside areas of the plain, there are quaternary coral limestones, almost all of alluvial deposit.

The cultivated Pingtung Plain area has a dimension of 113,000 ha, about 42 per cent of which are double cropping paddy field and almost 13 per cent are the farm owned by the Taiwan Sugar Production Company. The remaining cultivated areas are wanting of irrigation water.

The total irrigated area is 99,000 ha which corresponds to 87.7 per cent of the whole cultivated areas. In the order of crop plants classified by largeness of cultivated dimension, paddy is at the top followed by soybean, sweet potato, cane, banana and peanut.

The irrigation water sources are the tributaries of the Kaoping Creek and the rivers of other water system.

Ground water is also used complementarily because river water is not sufficient for irrigation. As for the ground water irrigation, deep and shallow wells are utilized of which the total number is 6,500 and the yearly amount of well discharge is $1{,}014\times10^6$m^3. Therefore, these wells are the important sources of irrigation water.

The specific capacity of deep well for irrigation in Pingtung Plain is about 3 m^3/min/m in the intake area of the plain and this is a very large amount. But the specific capacity decreased to 1 m^3/min/m according to the decrease of land altitude and in the coastal field at the lower reaches of the river, it decreased to 0.3 m^3/min/m.

The underground water level in the intake area is 10 to 30 m and in the conduit zone it is 0.3 to 2.5 m. The ground water flows in the coastal field.

Ground water can be classified into two types by its form; one is the unconfined aquifer zone in the upper and middle basins of the alluvial cone, and the other is the confined aquifer zone in the plain field.

The author determined the boundaries between free and confined ground water from the viewpoint of hydrogeology as is indicated in Fig. 1 by the broken line from B to B′. The mountain side area from this boundary is the unconfined aquifer zone and the seaside one is the confined aquifer zone.

Calculation of the amount of ground water flow

The amount of ground water flow was calculated with the existent data on the geological cross sections of the zone described along the ground water contour in Fig. 1 as A-A′, B-B′, C-C′ and D-D′. The cross sections A-A′ and B-B′ exist in the unconfined aquifer zone and that of C-C′ and D-D′ are in the confined aquifer zone.

Fig. 1. Sketch map of the Pingtung Plain drainage area

For the convenience of calculation, the cross section area was divided into some small parts, that is, twenty-two parts in a long cross section (350 km) and five parts in a short cross section. The water table slope I and the width of ground water flow L of every part were calculated with the coefficient of transmissibility T and the amount of ground water flow Q was obtained from the equation

$$Q=T.L.I \cdots\cdots\cdots\cdots\cdots \quad (1)$$

in which the transmissibility coefficient T was calculated from the results of the pumping test of thirty-four deep wells in that section. Then the total ground water flow was obtained summing up the values of each Q.

The ground water system was divided into free ground water and confined ground water by the hydrogeological structure of screen, and each contour map of a ground water surface was made to get water table slope. The amount of ground water flow in the dry season, May in 1968, was as follows; with the free ground water at A-A′ section in the middle basin of the alluvial cone, it was $8.65\times10^8 m^3$/year; and at B-B′ section in the lower basin, it was $14.13\times10^8 m^3$/year. As for the confined ground water at C-C′ section in the middle field, it was $1.45\times10^8 m^3$/year and at D-D′ section in the seaside area, it was $0.12\times10^8 m^3$/year.

In the rainy season, September in 1968, the amount of ground water flow was $9.0\times10^8 m^3$/year at A-A′ section, $16.8\times10^8 m^3$/year at B-B′ section, and $0.16\times10^8 m^3$/year at D-D′ section.

The increase of ground water flow was recognized with the free ground water but no great increase was detected with the confined ground water.

Ground water circulation proved by tritium analysis

Ground water circulation in free ground water layer seemed to be active from the data on geological structure and calculated ground water flow but confined ground water circulation remained obscure.

Then tritium analysis was undertaken in the author's laboratory with the water collected from four observation wells and deep wells in January 1970. The concentration of tritium was measured by liquid scientillation counter through the two-step electrolysis after distillation.

The artesian ground water collected from two places near Linpien Creek (collected at the depth of 64-134 m) showed similar low value of tritium unit of 5.12 and 5.13 TR. But that collected at the depth of 110–134 m in the deep wells near Tungkang Creek (Fig. 2 shows geological column) indicated a high tritium value of 56.1 TR.

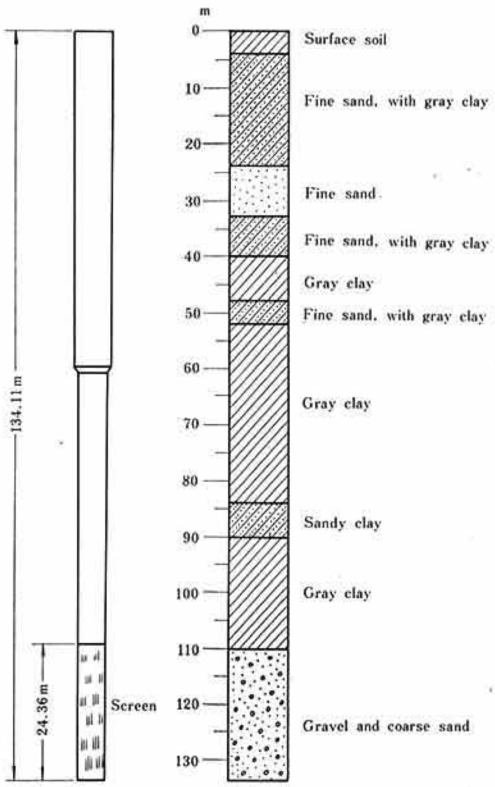

Fig. 2. Geological column of flowing well

As it is presumable from these values that there is certain consequence of the hydrogen bomb test in 1954, these ground waters might had been made after that test.

By the extraordinary high tritium value of the confined ground water collected near Tungkang Creek, it may be considered that a rapid ground water circulation exists.

Another rapid circulation can be presumed to exist near Linpien Creek considering the high concentration of tritium and the valleies shown in the ground water contour map.

Maximum amount of ground water usable for irrigation on plains

The possible amount of everlasting and secure well discharge without any hindrance of sea water intrusion and subsidence had been calculated.

Since the ground water flow which passes through confined aquifer had been calculated to be $1.45\times10^8 \mathrm{m}^2/\mathrm{year}$, future developmental ground water discharge was calculated with this figure as follows;

$$KA=\frac{Q}{H/L} \cdots\cdots\cdots\cdots\cdots \quad (2)$$

K=coefficient of permeability (m/sec).

A=total cross-sectional area of acquifer.

H=difference between the loss of head of the ground water at the outflow side of recharge area and that of seashore confined ground water (m).

L=distance between the measuring points of $H(m)$.

By substituting $Q=4.6\ \mathrm{m}^3/\mathrm{sec}$, $H=40-0.4=39.6$ m and $L=28{,}000$ m into (2) equation,

$$KA=\frac{4.6}{39.6/28{,}000}=3253.1 \text{ was obtaind.}$$

Then, as to the case of pressure ground water surface lowered to the limit of sea water intrusion in May and September in 1968, the safe yield (Q_s) of a ground water basin was calculated as follows;

$$Q_S=KA\frac{h}{1} \cdots\cdots\cdots\cdots\cdots \quad (3)$$

h=difference in elevation of confined ground water head from confined area to sea level.

l=distance from the border line between free ground water and confined ground water to the point where the safe yield was calculated.

As the results of the calculation of the safe yield of ground water basin at every geological cross section, available ground water amount may be $1.82 \times 10^8 m^3$/year, in the two-meter zone of ground water contour by pumping at sea water level.

In the same way, the obtainable ground water amount may be $4.35 \times 10^8 m^3$/year in the 20-meter zone of ground water contour.

The confined ground water amount which has been used for irrigation up to now are as follows;

below 2 m (ground water contour)	$0.13 \times 10^8 m^3$/year.
2–20 m	$2.36 \times 10^8 m^3$/year.
20–28 m	$1.68 \times 10^8 m^3$/year.
Total	$4.17 \times 10^8 m^3$/year.

The ground water amount which is available for irrigation in the future, therefore, may be about twice of the present amount.