Development of Groundwater Resources and Farmer-Managed Irrigation Wells in Shandong Province, China

Sun Fu Wen[61]

ABSTRACT

THIS PAPER DISCUSSES the status of the development of the groundwater resources and the organizational structure of the farmer-managed irrigation wells in Shandong Province, China. In order to develop and utilize groundwater resources scientifically and effectively, an overall investigation should be made first, to understand the distribution of the aquifer and law of movement of groundwater so as to assess the availability of resources. On the basis of such an investigation, unified planning and a reasonable layout of wells can be effected. The following model is applied to control the groundwater table, pumping-recharging by diverting Yellow River pumping (drawdown-recharging-drawdown). With this model groundwater recharging capacity can be enlarged; the recharging ability can be raised so that more surface water goes to the aquifer and becomes resources that can be reclaimed. Thus a stable aquifer will be sustained.

With the widening of the agricultural reforms associated with the household, contract responsibility system changes have been noticed in the agricultural economy, production group, distribution method and the requirements of the irrigation projects at large. Simultaneously much attention has been paid to the development of the groundwater resources. Farmers hold the opinion that groundwater utilization through wells has many advantages such as less investment, short construction period, instant effect, less influence from outside, reliability as a water source, flexible application and convenient management. Farmers call it "self-responsible water" or "self-managed water." Management systems of irrigation wells are mainly as follows: (i) village committee management; (ii) production group management; (iii) special household management; and (iv) special selectee management. All these systems permit the direct participation of the farmers in the management system ensuring timely irrigation and the increase of crop yields.

INTRODUCTION

Shandong Province lies in the lower reaches of the Yellow River, covering an area of 153,300 square kilometers (km^2). It has an agricultural population of 68,460,000 people and cultivated

---

61 Senior Engineer, Water Resources and Section Chief, Agriculture Water Department, Shandong Water Resource Bureau, Peoples Republic of China.

land of 6,852,000 hectares (ha). There are 4,700,000 ha suitable for well drilling, among which 3,370,000 ha with rich groundwater resources are suitable for shallow wells and 1,330,000 ha with more difficulties can be developed for medium and deep wells.

Since 1949, much progress has been achieved in the construction of irrigation wells. Earlier the wells were drilled by manpower and now power or semi-power machinery are utilized to drill wells to a depth of several hundred meters (m). Well drilling spreads from plain areas to hilly rock areas.

At present, there are 650 fully equipped irrigation wells with 766 sets of machinery. Two hundred and thirty thousand hectare have been developed under well irrigation accounting for 51.4 percent of the total effective irrigated area of Shandong. Wells have become the major mode of irrigation for agricultural production and 7,000 to 8,000 million cubic meters (m^3) of groundwater is used every year and each irrigates 4 ha of land on the average. Where there is a well, there is a piece of oasis and a scenery of a good harvest. For example, Shouguang County is a pure well irrigation area. There are 24,260 fully equipped wells through which 220 million m^3 of groundwater is exploited every year for the irrigation of 71,000 ha of grain land and some cash crops. The production yields of grain, cotton and vegetables are increasing year by year.

Development and utilization of groundwater resources demand a clear understanding of the distribution and recharge of groundwater as well as the necessary conditions for effective exploitation.

In 1973, a general survey of groundwater resources was carried out in 8,000 km^2 of Shandong. Drilling method was used in combination with surveys pertaining to exploitation, geophysical exploration, chemical analysis, pumping tests, etc. The movement law of groundwater was utilized to locate places suitable for well drilling. Maps of counties (1:50,000) and maps of prefectures and cities (1:100,000) were prepared to depict the following characteristics related to groundwater:

i) Depth of the bottom surface of shallow fresh water.

ii) Depth of the top surface of deep fresh water.

iii) Thickness of the sand layer with shallow fresh water and the distribution of water quality.

iv) Chemical varieties of shallow fresh water.

v) Depth of groundwater table (dry period, wet period).

vi) Characteristic value of groundwater table.

vii) Hydrogeologic section.

viii) Zoning of groundwater and exploitation conditions.

Information from the general survey and the production practice show that shallow groundwater has advantages such as large area coverage, quick permeability, convenient management, etc., while the deep groundwater does not have the above-mentioned plus factors and can be used only as a reserved source. Therefore, making full use of the shallow groundwater should be promoted in the development of groundwater resources.

UNIFIED PLANNING AND REASONABLE ZONING

Surface water and groundwater are transferable and needs integrated planning, reasonable zoning and comprehensive utilization, so as to gain maximum efficiency. The present situation of

Shandong is that places with sufficient groundwater are also rich in surface water. When both sources are equally rich there is a high level of irrigation guarantee. However, in places short of groundwater, some of the irrigation projects for surface water are not equipped to ensure constant supplies. Hence, the water resources cannot be fully utilized. Therefore, it is very necessary to study and work out the various zones which are technically feasible and economically viable.

Well Irrigation Zone

In the pre-mountain alluvial plains and the old river beds where there are rich water resources, wells provide the main source of irrigation and act as an anti-drought measure.

Well Irrigation Zone in Combination with Canals

In places relatively rich with water resources, the engineering structure of wells and canals is very significant. The wells play the major role with canals as an auxiliary measure so as to raise the regulation ability and ensure the water use of the farmlands.

Canal Irrigation Zone in Combination with Wells

In places short of groundwater, surface water should be fully utilized. Canal irrigation plays the major role and well irrigation is auxiliary.

The above zoning is based on the quantity of the local groundwater available. Nevertheless, in different zones surface water is used as a major or an auxiliary measure. However, Optimum benefit is made possible through combined and alternate use of water resources.

CONTROLLING THE GROUNDWATER TABLE TO IMPROVE THE STORAGE AND REGULATING ABILITY

In the irrigation district of the Yellow River Diversion, water quantity diverted from the Yellow River is bigger in volume than the groundwater exploited. In some parts of the district, the water table becomes high due to the irrigation recharge from the Yellow River waters, and regulation ability in such cases is low. For example, in Weishan Irrigation District, the water table before irrigation is about 2.5 to 3 m below surface. One spell of irrigation can raise the water table by 1.67 m on the average and by a maximum of 1.81 m. Observations show that there are 21,395 km^2 of area with a water table lying less than a 2 m depth (42 percent of the total area). However, in 6,765 km^2 this level lasts for 120 days and in 6,888 km^2 it lasts only for 60 days. The high water table is the main cause of surface salinization.

Saline soils also characterize the area from Jiazheng to Xueyan of Guanxian County where, for the past ten years, wells have been playing the major role in irrigation. In this area, the annual groundwater use is 120 to 150 thousand m^3/km^2, the water table is kept at a depth between 3 - 6 m and 6,700 ha of saline lands are brought under control. According to the measurements of Jiazheng Rainfall Station, when daily maximum precipitation is 141 millimeters (mm) and three-day maximum precipitation is 154 mm, there is nearly no runoff. In the circumstance, most of the rainfall is converted into groundwater.

The conclusion can be drawn from the above two examples that when the water table is controlled at an optimum level, storage capacity is enlarged, more water is recharged to aquifers and the regulation ability is improved.

Controlling the groundwater table is a complicated issue directly related to technique, economy, management, policy and legislation. However, from the point of view of technique, long-term and steady development of groundwater can be ensured by taking the following measures: (i) adopting a suitable engineering structure for shallow wells and canals; (ii) combining drainage and irrigation with storage and recharge; (iii) unified dispatch of the "three water"; and (iv) applying the model of pumping irrigation by diverting Yellow River pumping (drawdown-irrigation recharge-drawdown).

The kind of water source used in applying this model depends on the groundwater situation. In general, well irrigation is used in spring to lower the water table for bigger storage. When the water table drops below 7 m, it is proposed to divert surface water for irrigation. When the water table stays between 5.5 to 7 m, 60 percent of the area is allowed to be irrigated with diverted water. When the water table stays between 4 to 4.5 m, only 30 percent of the area is allowed to be irrigated with diverted water. When the water table is less than 4.0 m, diversion is forbidden and only well irrigation is allowed. In this way, surface water plays the double function of irrigation and recharge, precipitation recharge is enlarged during the flood season and it can help reduce evaporation and gathering of surface salinity. Thus the multiple purposes of drought resistance, salinity treatment and increase of regulation ability are realized, providing for long-term, steady and balanced exploitation of groundwater resources.

ORGANIZATIONAL STRUCTURE OF FARMER-MANAGED IRRIGATION WELLS

The farmers think irrigation wells are less influenced by outsiders than other kinds of irrigation projects and that they need less investment. These wells can be constructed and operated by several households joining together. The well is drilled, equipped with completed pump sets and used throughout the year. The farmers call this type of irrigation "self-managed water" or "self-responsible water" through which increased production can be ensured during the whole year.

The following are the four types of farmer-managed irrigation wells:

Wells Managed by Village Committees with Contracts

All the facilities of the irrigation wells are owned by the village under the unified management of the Village Committee (the basic administrative unit in the rural areas of China). This type of management accounts for 27 percent of the total irrigation wells.

Under the village committee, an irrigation service team is set up. For example, in the rural areas of Yantai City, irrigation service teams are set up in most of the villages. These teams are responsible for irrigation construction and management of the whole village. It implements "four aspects of unified management," i.e., unified planning for well drilling, unified management of facilities, unified distribution of irrigation water and maintaining unified standards of water charges. Wells are contracted to the members of the service team. "Five fixes and one reward" responsibility system is implemented. This includes fixing (i) personnel, (ii) irrigation tasks, (iii) consumption of fuel and electricity, (iv) repair fee, and (v) salaries. At the end of the year, a reward is given according to the fulfilling of the targets. This type of management is further developed by the farmers of Haiyang County. First, an irrigation management organization is set up in the village consisting of a village cadre, an operator, an electrician and a cashier, whose tasks are to operate and manage the irrigation projects and collect water charges. Second, projects' accounting system is set up. Independent accounting is practiced to be self-responsible for the

benefits and losses. Third, reasonable water pricing based on costs is effected. Fourth, through a consultative process with the farmers, the depreciation fee and a part of the profit are taken out for the repair and rehabilitation of the projects.

Production Group-Managed Wells with the Contract and Reward System

The irrigation wells and the pumping facilities are owned by the farmers of the whole village. The production group is formed by farmers whose land is within the effectively controlled area of the well. The well is used and managed by the production group. Contracts of duties and rewards are made to the persons concerned. This type of management accounts for 48 percent of the total wells.

Detailed issues such as irrigation priority, water cost for one time of irrigation per mu (15 mu = 1 hectare), repair cost and payment of the contractor are discussed and determined by the farmers of the production group. Most of the production groups chose the average value of the past three years' expenditure to call for tenders. A contract is made between the production group and the contractor. The money saved belongs to the contractor and the money over-spent should be borne by him alone. If the work is well done, a sum of money is raised by the farmers at the end of the year to reward the contractor. If the work is not accomplished and if there is no special excuse the contractor should compensate for some of the losses incurred.

Specialized Household-Managed Wells

In this case, the village committee undertakes repairs and provides the well, pumping equipment, engine house, water tank, canals and commonly used instruments for the irrigation system to operate. Improvements to well discharge, pumping situation, soil quality, water price and irrigation area are effected through a tendering procedure open to all farmers. The households chosen sign the contracts with the village committee. Some of the households pay water charges according to the money earned by selling the products, some according to the irrigated area and still others according to the watering period. A certain proportion is given to the village committee as depreciation cost and the rest belongs to the contractor. This kind of management accounts for 22 percent of the total area.

Selected Operator-Managed Wells with a Land Payment System

The irrigation project belongs to the whole village and the costs of operation, repair and depreciation are paid by all farmers in the village. The village committee selects an operator with a high sense of responsibility and he is entrusted with the management. The operator has to take care of the wells, engine house, pump equipment, water tank, canal and he should also irrigate the land in time. A piece of land of 0.1 to 0.2 ha around the well is allocated to the operator as payment for his management functions. He gets irrigation water free of charge for the cultivation of this land. The income from the land is the salary he receives for the management. A farmer-user can make a demand to the operator for irrigation at any time and the costs of electricity and fuel should be paid by the user.

Through many years of experience, all types of farmer-managed irrigation wells have gained good results. First, the management person is active, responsible and highly efficient. Second, the management person has detailed and clear responsibilities. He can repair and maintain the equipment in time, put the instruments in order and keep the pumping equipment in good and safe condition, so as to start the engine at any time. Third, the core of the system of responsibility is that working is directly linked with payment. More work means more money and the savings belong to the management person himself. Therefore, the management person is thrifty and

hardworking, waste is reduced, energy is saved, cost is lowered, steady and high yield is ensured and the farmer income is increased year by year. Our experience shows that if the farmers are organized properly, there will be a bright future for the farmer-managed irrigation wells.

CONCLUSION

Both groundwater and surface water resources of the Shandong Province should be treated as an integrated whole in planning water resources development. Continued surface irrigation in places such as the Weishan District has led to a steady rise in the water table increasing the salinity of the soils. In areas with saline soils, extraction of groundwater exerts a salutary effect in controlling salinity. Further, groundwater development has not only assured drought-resistance to crops but has also provided a basis for a balanced development of water resources. Factors such as comparatively low investment, sense of ownership, low cost of operation and the ability to cater to water users' demands have made the farmer-managed irrigation systems more attractive to the farmers.