Economics of Irrigation Return Flow Quality

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Concern for the quality of our nation's waters is not new. The "Harbor Pollution Legislation of 1888" and the "Rivers and Harbors Act of 1899" evidence a longstanding concern for water quality. From that time until the present a number of legislative enactments have reaffirmed a national commitment to the control of water pollution (e.g., Water Pollution Control Act of 1948, The Water Quality Act of 1965, The Clean Waters Restoration Act of 1966). The major emphasis of past activity has been the control of point sources of discharge from municipalities and industries. Only recently have pollution problems associated with agricultural water use been addressed in national legislation [P.L. 92-500]. Perhaps the most difficult of these problems involves irrigated agriculture.

Initial efforts to regulate pollution from irrigated agriculture were formulated in terms of the same methodology developed for controlling municipal and industrial sources of pollution. Specifically, the Environmental Protection Agency (EPA) has attempted—without much success—to implement its permit system for water discharges from irrigated agriculture [P.L. 92-500, Sec. 402].

The failure of the permit system to control irrigation return flow quality can be traced to two major causes: the diffuse nature of the pollution source and the lack of markets in allocating water resources. While the first cause is widely acknowledged, the second cause is not clearly understood.

The purpose of this paper is to examine the allocation of water resources and to suggest a possible solution to the problem of pollution resulting from irrigation. The paper examines four specific topics: 1) the physical nature of the problem; 2) the economic nature of the problem; 3) present types of adjustments to the problem; and 4) a market solution.

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Physical Nature of the Problem

Water utilization for irrigation can be conceptualized as passing through three phases, as shown in figure 1. The water is diverted from a stream, applied to crops, and that portion not consumptively used returns to the stream. Irrigation return flow quality is a function of the water's travels from diversion to discharge.

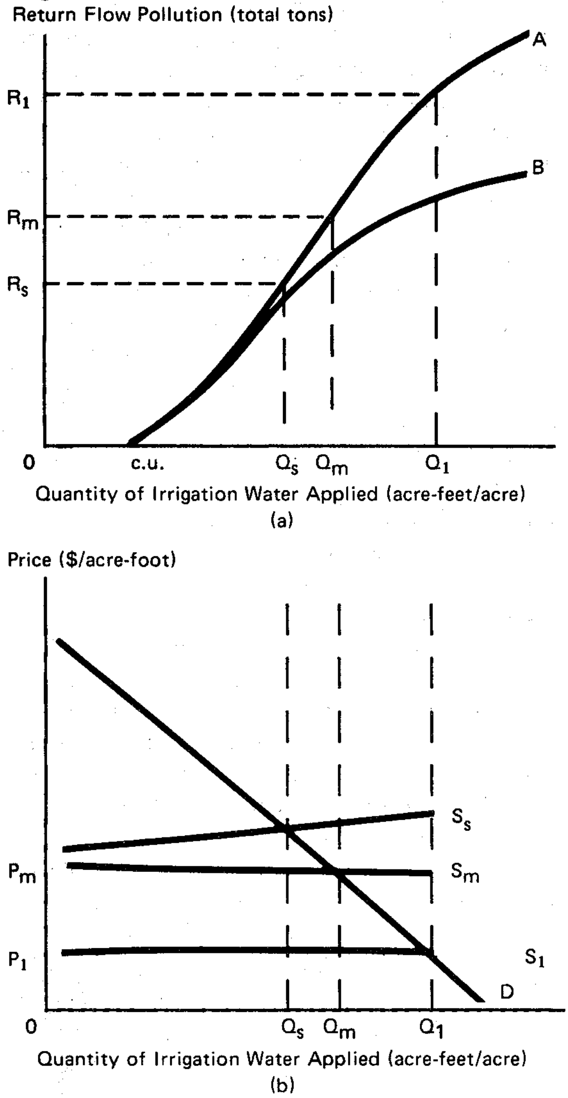
Fig. 1. Phases of irrigation water use

Diversion → Application → Discharge

The amount of pollution resulting from the irrigation process obviously depends upon a large array of variables, such as soil type, slope of field, type of crop, stage of crop growth, irrigation management, and quantity of water applied. This discussion focuses on the management and quantity of irrigation water as the most critical variables.

In general, the amount of return flow pollution is positively correlated with the per acre quantity of irrigation water applied, and negatively correlated with the management of irrigation water, as shown in figure 2(a). As water is applied beyond the consumptive use requirements of the crop (c.u.), return flow pollution tends to increase at an increasing rate with additional water up to a point of application beyond which it increases at a decreasing rate. The relative position of this relationship depends upon the level of water

Fig. 2. Water allocation/pollution relationships



management, so that curve A corresponds with a low level of management and curve B with a high level. The actual slope and shape of these curves will vary between differing areas with different physical conditions. Site specific investigations are required to derive exact relationships; however, figure 2(a) serves to illustrate the general conceptual relationship.

Economic Nature of the Problem

In the Western United States, irrigation water is allocated by the doctrine of appropriations. That is, first in time, first in right. In general, the cost of irrigation water is the average cost of its conveyance from the stream to the farm. This cost is usually fixed, such that the supply curve under the doctrine of appropriations appears as a horizontal line (S_1), as shown in figure 2(b).

With a normal downward sloping demand curve (D), the farmer will rationally demand Q_1 units of water under the doctrine of appropriations. That is, a profit maximizing farmer will select that quantity of water which equates his marginal cost with his marginal benefit. The actual allocation will depend upon additional physical and legal considerations, but the tendency will be towards an allocation of Q_1 units of irrigation water per acre. Since there is no opportunity to transfer water, he will apply this entire allotment to his land.

If irrigation water was not allocated through a legal machanism, but rather through an economic market, the price of water would be determined by supply and demand among all water users. The intersection of the upward sloping market supply curve and the downward sloping market demand curve yields an equilibrium price to which all water users, as price takers, respond. The water right owner then becomes both a demander and a supplier of water. He may either use or sell any or all of his water up to the absolute limit of his water right allotment. Each unit of water consumed by an individual farmer's irrigation would have an opportunity cost equal to the market price (P_m) in alternative uses. A market mechanism, which allows for transfer of water among users, causes the farmer to respond to a supply schedule reflecting both conveyance and opportunity costs (S_m). Over the range where the value of the marginal product–as reflected by his demand curve–is greater than the market price–as reflected in his supply curve–he will apply water to his own fields. He will sell all water beyond the point where D equals S_m. Thus, his per acre application would decrease from Q_1 to Q_m. Although the total quantity of water used in the entire market would probably remain constant, the reduction in per acre application rates generates water for additional acreage or other high-value uses and simultaneously reduces the level of return flow pollution.

Finally, if water quality is considered, the supply function may be more steeply sloped. Society as a whole has an interest in how water is used, so that an additional cost is associated with the use of water for irrigation–a pollution cost to society. The sum of the private and social marginal costs of irrigation water results in a supply schedule (S_s) above the market supply curve (S_m). The optimum per acre application of irrigation water is, thus, O_s units, which is less than both the application rate under the doctrine of appropriations (Q_1) and the market solution (Q_m).

Adjustments to the Problem

Adjustments to the problem of irrigation return flow quality can be categorized according to their impact on the three phases of irrigation water use shown in figure 1. In general, present adjustments attempt to correct return flow pollution at application and discharge phases of irrigation water use.

The permit system is directed towards the third phase of irrigation water use. That is, it attempts to regulate the quality of water discharged from irrigated farms. Irrigation return flows, however, are diffuse and not easily identified with their source. Both surface and subsurface return flows freely mingle from a multiple of sources so that measurements and identification of pollution sources are extremely difficult, if not impossible.

Furthermore, the permit system does not seek to reduce pollution to its optimum level, but rather to license an arbitrary level of pollution discharge. Indirectly this mechanism may affect the relative price of water and, thus, the profit maximizing mix of inputs, but no necessary relation exists between monitoring discharges and the efficient allocation of agricultural resources.

In at least one case, the essentially impossible task of monitoring discharges and the arbitrary nature of the regulations has caused implementation of the permit system to be a sham. The Department of Ecology in the State of Washington has realized the futility of implementing the permit system and has arbitrarily issued permits for the wastewater [excess water which is not applied to the fields, but is passed back into the stream] from irrigation districts. This is nothing more than token compliance with a law aimed at controlling agricultural pollution in the discharge phase. Indeed, such an action is as much an indictment of the approach as is the outright refusal of many states to even attempt to administer the program.

More recently, attention has focused on the application phase of irrigation water use. Here, the mechanism of adjustment has been to improve on-farm management of water. In general, this entails the addition of capital and labor inputs to improve the efficiency of water use and reduce water pollution resulting from poor farming practices.

This approach is often expensive and implementation involves detailed studies and direct government intervention. The major problem with this mode of adjustment is that unless the farmer is not currently maximizing profits by selecting that mix of inputs which equates the dollar return per dollar spent on each input, he will resist any change in the input mix. Reducing pollution by encouraging increased capital and labor inputs will, therefore, require subsidization of the farmer. Moreover, this approach involves extensive and, generally, expensive investigation to determine the appropriate new mix of inputs.

A case in point is Grand Valley, Colorado, where there is an acute salinity problem in the Colorado River. Between the mid-1960s and 1977, over $50 million has been or will be spent on researching the causes and possible solutions to the Colorado River salinity problem. The irrigation system and on-farm structural improvements that are proposed to reduce the water quality problem are projected to cost approximately $100 million. The total cost in research and structural improvements approaches $2,800/acre for the 55,000 irrigated acres. The market value of agricultural land in the Valley is only about $1,500/acre.

Market Solution

Finally, this discussion leads to the consideration of methods for reducing return flow pollution through adjustments in the first or diversion phase of irrigation water use. If, indeed, excessive amounts of water are being combined with other inputs, then the indication is that this resource is underpriced. That is, if return flow pollution results from an improper mix of inputs, then the cause may be that the price of water (P_1) is too low.

The reasoning for this conclusion is illustrated by combining figures 2(a) and 2(b). For simplicity, only management level A is considered. Thus, figure 2 indicates that under the present doctrine of appropriations, the comparatively low price of irrigation water induces farmers to use Q_1 units of water resulting in a pollution level of R_1. Under a market system where water could be freely bought and sold for all purposes, the allocation of water to irrigated agriculture would be Q_m ($<Q_1$) and the level of return flow pollution would be R_m ($<R_1$). In addition, the increased price of water ($P_m>P_1$) would affect the mix of inputs such that management might improve, thus shifting downward the pollution curve in the upper graph and reducing the final level of return flow pollution.

The point is that a freely operating market for water would reallocate water automatically and without outside interference. The consequence would be a reduction in the level of return flow pollution both as a function of the reduced level of diverted water and improved management. That is, establishing a market for water would reallocate the quantity of water used for irrigation from Q_1 to Q_m, thus reducing the return flow pollution level from R_1 to R_m. This may also shift pollution curve A downward, thus reducing pollution below R_m.

Under some present institutional arrangements, it is impossible to transfer ($Q_1 - Q_m$) units of irrigation water. Water law in the Western states generally restricts water transfers to the volume of consumptive use (i.e., the difference between diversion for beneficial use and return flow), in order to prevent damage to downstream appropriators [Hartman and Seastone, p. 19]. A typical legal statement of junior appropriators's protection is that they "have vested rights in the continuation of stream conditions as they existed at the time of their respective appropriations, and they may successfully resist all proposed changes in points of diversion and use of water from that source which in any way materially injures or adversely affects their rights" [Farmers Highline]. Thus, the present amount of return flow, RF = Q_1 - c.u., must remain available for downstream users. Only if the farmer's consumptive use requirements are reduced can a transfer take place.

There is a growing body of economic and legal literature addressing the complex problems involved in water transfers and the return flow issue [e.g., Ellis; Hartman and Seastone]. Much research and testing is still required to generate workable institutional arrangements under which a private market could freely operate. Even if present institutional arrangements allowed for a private market solution, a social optimum may still not be achieved. Return flow represents an external diseconomy to society so that the actual cost of use is greater than the private cost. The socially optimum allocation of water to irrigation is Q_s ($<Q_m$) with a corresponding level of return flow pollution R_s ($<R_m$). In the past, recognition of the external diseconomies that are created by irrigation return flows has led us to seek a solution for the entire problem (from R_1 to R_s) in outside adjustments (e.g., government construction and subsidy programs).

But, the place for outside adjustments is in the interval Q_m to Q_s (R_m to R_s). That is, tax-subsidy, legal and engineering schemes for reducing pollution should be applied here at the margin to achieve the social optimum. The interval Q_1 to Q_m is most efficiently attacked by market mechanisms and only at the margin do the extra-market approaches become appropriate.

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