

water supply is economically justifiable in comparison with other types of investment such as tubewell systems which have a smaller degree of "lumpiness" than dams.

Lining of Canals with Sealants

A final analysis carried out with the digital computer related to the use of sealants to reduce leakage from canals. The lining of canals and other components of the distribution system with asphaltic emulsion sealants and similar compounds to retard leakage was found to be economically justifiable only if the cost per application is less than about 2¢ per square foot of canal bottom. A benefit-cost analysis was carried through for each of eight different cropping patterns. The crops, yields, and prices were similar to those used in Chapter 5. Costs of tubewells alone to provide the seasonal irrigation water requirements for each pattern were compared with costs of tubewells plus sealants to provide the same requirements. In the latter case, the tubewells were smaller and less expensive because the sealants reduced leakage and therefore less pumpage was required to meet a given irrigation water requirement. The assumption was made that all canal and watercourse bottoms would be treated with sealants and that this would reduce leakage by fifty percent. It was further assumed that sealants would have to be injected once every five years. In all of the cropping patterns studied, however, the saving gained by smaller well installations was more than offset by the added cost of lining, so that the designs with tubewells alone were invariably less expensive when lining costs were 2¢ per square foot. The effect of the lining was to reduce average pumping rates during the year. However, maximum pumping rates were reduced relatively less. Tubewell costs in the cases studied were more nearly proportional to the maximum pumping rate than to the average pumping rate.

Designs using both tubewells and sealants were found to be very much superior to designs without tubewells that relied entirely on lining to provide additional irrigation water. Although additional irrigation water can be obtained by lining alone, it is available only during periods of high river flow. With wells, water is available throughout the year as needed. It may be had in dry seasons and wet seasons, in dry years as well as wet years with the aquifer serving as a gigantic storage reservoir. Thus while it is possible to reduce the cost of providing additional water by using lining alone, the benefit from the crops was impaired because of the non-optimal distribution of water during the year. Much of the loss in benefit was due to the reduction in production of winter wheat.

Hydrological Research

Our plan for the development of the water resources of West Pakistan requires a large capital outlay for water management works. To insure