Paper No. 329
Year 1958

THE PHENOMENA OF LOSSES AND GAINS IN THE INDUS RIVER SYSTEM

S. S. KIRMANI

Paper No. 329
Year 1958

THE PHENOMENA OF LOSSES AND GAINS IN THE INDUS RIVER SYSTEM

By

S. S. KIRMANI

A correct estimation of river supplies, available for irrigation and other uses in the Indus River System, largely depends upon a proper understanding of the phenomena of losses and gains. Presently no relationship is available between river flows and losses/gains in this system. This paper describes the development of a new relationship with sound theroretical background and detailed analysis of ths historical data.

Indus River System covers an area of about 348,000 square miles. It comprises the main Indus and its six major tributaries: Kabul on the right bank and Jhelum, Chenab, Ravi, Beas and Sutlej on the left bank. The Indus valley is composed of alluvium and depth of alluvium ranges from 5000 to 10,000 feet. The rivers pass through vast alluvial plains. Longitudinal slopes in Punjab become very flat like 1 foot per mile which further decrease to 0.5 foot per mile in the lower reaches. All the rivers of Indus system have characteristics of changing their courses and this often made it impossible to locate the sites of many old rivers.

Snow is the source of water for head reaches of most of the streams. In the sub-mountainous regions precipation averages from 30 to 40 inches and decreases to 15 inches in Punjab and 5 inches in South. The plains are therefore classified from semi-arid to arid zones. Local rainfall is not consistent in terms of quantity, incidence and duration and mainly concentrates during the monsoons (June to September). The average summer temperature in the plains is 95°F with maximum upto 120°,

whereas average winter temperature is 60° with minimum occasionally reaching freezing point.

Extreme variations in flows is the typical feature of the rivers of the Indus basin and the normal summer discharge may be as high as 20 times of the winter minimum. Water level normally rises in the start of April with the melting of Himalayan snows, reaching a maximum during July as a result of the monsoon rainfall, falling off in September and hitting its lowest during October to March months. Gross area of the Indus Basin in Pakistan is 131 million acres, 75 million acres of which is culturable. Only 27.5 million acres are used for crops, of which 90% produces one crop per annum. Actual irrigated area of 21 million acres represents 76% of the cropped area.

Every river in the Indus basin has a phenomena of losses and gains with an ultimate effect on water for irrigation. River loses water during high flow partly by percolation through the porous bed and bank formations and partly by evaporation and transpiration within the river valley. Regeneration occurs during low flow by the returning of water from river bed and bank formations. The losses during the months of April, May and early June determine the available river supplies for sowing of the Kharif crops. Rabi crops in some areas depend almost entirely on the regeneration from mid October to March. These losses and gains. occur in great magnitude and their advance forecast is essential for an efficient and equitable distribution of the river supplies.

Basic factors casusing losses include absorption, evaporation, consumptive use of vegetation in the river valley and channel and bank storage. The gains result from percolation of ground water, return flow from channel and bank storage, rainfall and unmeasured inflows. These factors depend upon many subsidiary factors. Wetted perimeter, depth of water, soil conditions, rate of change in discharge river stage, degree of saturation. Shape and size of river, rainfall etc. are some of the important subsidiary factors. The problem becomes more complex when gain factors operate simultaneously with the loss factors. Prediction of their combined effect in such cases may turn out to be quite misleading. All the dependent variable factors can be expressed as a function of the river flow. A reliable loss equation can be worked out by considering the loss factors alone neglecting the cumulative

effect of all gain factors. Similarly true gain may also be worked out by ignoring the loss factors. Apparent loss and gain expressions, given by the Author, however, depict cumulative net effect of all these factors. These equations reveal that the losses are not simply a direct function of the concurrent river discharge Q and therefore Method for Proportionality, according to which losses are a direct function of the river discharge, is basically incorrect.

Bank storage is the main source of regeneration. Bank storage is recharged either by the river in high flow or by the ground water in the doab or by both. Extensive studies were carried out to find out a precise role of the above two causes. The studies established the fact that river flow and not the ground water is the main source of recharge and that there is a definite relationship between the quantity of river flows and the magnitude of regeneration. Valley storage is substantial in alluvial rivers like the Indus System because they have wide and shallow valleys. The effect of valley storage on the river flows can be found out by the use of the Stage Storage Method of Flood Routing.

In establishing the phenomena of the losses and gains in the Indus River system certain basic principles were formulated which have led to the development of important hypothesis. More important of these principles are direct proportionality of losses and concurrent flows, gains and antecedent flows, gains and drop in the river stage and inverse proportionality of losses and antecedent flows, gains and concurrent flows and gains and time lapsed since the previous high flows. For a better understanding of the losses and gains phenomena, effect of the causative factors on the losses and gains must be considered over a sufficiently long period. For a systematic study the flow hydrographs were divided into 5 periods: two rising periods from April to July, two falling periods from August to October and a low flow period from October to March. The above are the general periods for the eleven reaches considered on the Western Rivers. This method of division of hydrographs is in accordance with the method adopted for the study of channel losses in the Upper Colorado River System of USA.

The effect of concurrent and antecedent flow was measured by the volume of flows, the magnitude of individual peaks within the period and by the magnitude of rise and fall in river stage. The effect of time

lapsed since the previous high flows was measured in terms of the number of days from the centre of gravity of the high flow mass to a fixed reference data of the low flow period. Method of multiple linear correlation was used for the establishment of different relationships because it provides a simple, practical and useful tool in the analysis of hydrological data. The independent X variables considered in the analysis are concurrent flows, the antecedent flows, valley storage and the time lapsed since previous flows whereas Y is the dependent variable and may be loss or gain. The correlation analysis was carried out for all the eleven reaches on the three Western River i.e., Indus, Jhelum and Chenab and for three reaches on the Eastern Rivers Ravi and Sutlej. The analysis has shown that concurrent and antecedent flow are important factors contributing to losses and gains. The amount of release from the valley storage in falling period has also an effect on gains. The analysis also established the fact that gains in the low flow period are also influenced by the time lapsed since the previous high flows. These results are in agreement with the theroretical principles and confirm the validity of the hypothesis.

Statistical measures such as the co-efficient of correlation, standard error of estimate, etc. show the significance of the relationships and for this study these parameters are in the range of acceptable limits. However these co-efficients can be improved further by including other relevant factors like precipitaion, temperature, unmeasured flows etc. All the 53 formulae for losses and gains for the eleven reaches on Indus System give the same consistent relationships. Consistency of the relationships provides a more reliable measure of their significance than indicated by mathematical procedures. A comparison of the estimated values of losses and gains with the actual values in all the 31 years of available data was carried out. The estimated values of losses and gains conform closely to the actual historical values in 75 percent of the cases, whereas the remaining 25 percent cases involved extraordinary value of loss or gain resulting from unusual rains or floods. The degree of agreement between estimated and historical values is quite satisfactory. The formulae are quite adequate for the water studies as these studies assume no change in factors like rainfall and unmeasured flow etc. The future forecasting based on the formulae may have some errors because of the absence of effects of above noted factors. These formulae do, however, provide a guide for extrapolations beyond the observed range as against blind guess work.

A comparison of the results with those given by the proportional method and actual values have established a better reliability of the frmulae than that of the method of Proportionality. This study has shown that both concurrent and antecedent flows have a significant effect on the magnitude of losses and gains. Magnitude of releases from the valley storage and the time lapsed since previous high flows also influence the gains. Evaluation of the established relations shows that they are dependable equations for estimating as well as forecasting.