DISSERTATION

DEVELOPMENT OF OPERATIONAL AND MANAGEMENT STRATEGIES FOR GRAVITY FLOW SUBSURFACE CONTROLLED DRAINAGE SYSTEMS

Submitted by

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ABSTRACT

Extensive subsurface drainage system was installed in district Mardan in the North West Frontier Province of Pakistan in 1987 to control increasing water logging and salinity. Several recent studies have indicated that the subsurface drainage system has enormously lowered water table in certain areas due to extensive drainage network. Scarcity of irrigation water and over-drainage have influenced the yield of major crops. The reduced irrigation supply, drought conditions and over-drainage have dropped the groundwater to a disastrous level. Thus the present groundwater level cannot contribute to the crops. Therefore, a study of controlled subsurface drainage technique was initiated to observe the temporal and spatial variations in water table depths under various modes of canal irrigation and by monsoon rains.

Two artificially drained areas, consisting of 40 ha (104) and 160 ha (106) respectively, were controlled and selected for extensive monitoring. A total of 98 observations wells (7.6 cm dia. and 4.1 m depth) were installed to observe water table fluctuations. Collector at its exit in drainage unit 106 was controlled to raise the water table and this area was divided into ten zones. Each zone was separately assessed to analyze the groundwater impact in response to the control technique adopted for mitigating drought in different strategies of the canal operation. The interaction of groundwater level on irrigation depth, crop yield, water use efficiency and water saving were also studied. The drainage unit 106 was calibrated for the year 1999 for all operational strategies of the canal and seasonal variations on the basis of physical data collected in the field. The model was validated for the next year, 2000. The simulation criteria of the validated model was devised for year 2001. The applications and scenarios in terms of sensitivity in response

to the time constant and variant parameters and packages were also applied to diagnose and for in-depth study of the model area.

Each of the two areas monitored in the study behaved differently. It was observed that in one of the areas design water table depth at 1.1 m was maintained. This was regarded as proper functioning of the control technique applied to the subsurface drainage system. The results from this area showed that 25 to 55% of the time throughout the year achieved this objective whereas in the second area desired water table could not be maintained and water table depth in this area remained between 2.0 to 2.7 m causing unnecessary water stress to plants. In addition, the proper functioning of control techniques in subsurface drainage system supplemented very efficiently to retain the groundwater level to the optimal limits in dry season and to the design ones in the others for timely needs of the crops. Also rainfalls have significant impact on the spatial and temporal behaviors of water table depths in both the areas during the monsoon season.

It was observed that water table in the former area is mostly controlled by the operation of the irrigation canal. Significant contribution of seepage in the up slope of the collector drain considerably reduced, the irrigation depths. During canal closure period, the water tables in the study area dropped to the limit of 2.3 m to 3.25 m. After reopening of the canal, the water tables in sections II, III and IV rose from 2.55 m to 0.70 m - *GS*. During this period the water levels near the canal reached to the design level. The maximum yield of 6.5 tons/ha at the down slope end of the lateral drains in section II was obtained resulting in maximum water use efficiency of 0.93 kg/m^3. However the minimum yield of 3.5 tons/ha at the up slope side of the lateral drains in section I was obtained resulting in lowest water use efficiency of 0.35 kg/m^3 near the deep surface drain (5 m). The impact of controlled subsurface drainage in zones 2, 3 and 7 resulted in best maintaining the optimum groundwater level and moisture content. Therefore large amount of extra irrigation water applied (ranging from 23 to 129 % of the amount actually required) in different zones of the controlled area can be saved.

Maximum yield of sugarcane in *MGV* drainage unit was obtained from zone 1 due to the control point, and in zone 4 at the up-slope side of the collector due to seepage from the canal. In the *LSV* drainage unit maximum yield was obtained in the middle of the area where the collector was illegally controlled and at the branch collector near the canal due to heavier extra irrigations of double supply and additional seepage. Generally, the whole area shows that optimal yield of sugarcane can be obtained when the groundwater fluctuates around 1.8 m - *GS*. However minimum yield is obtained where ground water level remains in the range of less than 1 m - *GS*.

MODFLOW-predicted distribution of recharge from the irrigation system more or less represents the observed field conditions. During closure period the simulated groundwater is only exploited by the sub-surface drainage system while the open drain remains absolutely inactive at the lowest groundwater level. As the irrigation canal re-opens, the highest simulated groundwater level on 23 % of the irrigated area, in the middle and close to the irrigation canal is mostly on the up-slope side of the lateral drains of the controlled collector. With the passage of time the highest water table developed slowly and then steadily slumps down back towards the medium level in pre-monsoon season due to high crop water requirements and dry season. As the rainy season of monsoon starts, the highest groundwater level on maximum of the area (from 3 to 31 %) at the up-slope side of the controlled lateral drains increases. During the rotational period of the canal, recharge applied from intermittent supply of irrigation, rainfall, and seepage from inland watercourses (as a whole 50 %) are completely utilized for crop water requirements. Unavoidable deep percolation or quick sub-surface drainage (33 %) occurs due to which the existing storage capacity (17 %) is exploited.

The sensitivity analysis shows that vertical hydraulic conductivity (K_v) and effective porosity *(P)* were non-significant parameter. However the horizontal hydraulic conductivity (K_h) and specific yield (S_y) were significant parameters and play an active role in control of sub-surface drainage system. In addition to the impact of the open deep drain with reference to higher elevation of its irrigated land, zone 6 physical phenomenon itself has a great role in its exploitation. The recharge has more positive impact when increased. Similarly recharge of zone 9 nearly plays the same role as the specific yield close to the deep open drain in zone 6. The increase or decrease of recharge by half of the calibrated value in zone 6 is helpful during the closure period of the canal when the groundwater level is deep enough with respect to the ground surface or root zone of the crops. The extensive increase beyond these limits is absolutely of no use in this regard. The sensitivity of the controlled sub-surface drainage system to increase or decrease in recharge is adversely affecting the groundwater level of controlled drainage system.