THESIS

DESIGN OF SUBSURFACE PIPE DRAINAGE CONSIDERING ENVIRONMENTAL AND ECONOMIC SUSTAINABILITY WITH IRRIGATION OPERATIONS

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ABSTRACT

Subsurface pipe drainage interventions are introduced to mitigate the adverse environmental impacts on part of waterlogging and salinity and maintaining a favourable salt and water balance in the root zone. Conventional steady state design approach is based on average recharge conditions results in shallower watertables (under drainage) during monsoon (2-3 months) and deeper watertables (over drainage) in non-monsoon period (6-9 months). Too shallow watertables or under drainage results in crop damages while deeper watertables or over drainage induce wastage of applied irrigation water. Deeper drains however permit wider drain spacing resulting in lower drainage installation cost. The present study was carried out to find out an optimum subsurface pipe drainage design solution in terms of drain depth, W and spacing, S that would ensure maximum utilization of the available water resources without any wastage at minimum system cost while maintaining sub-irrigation and lower salt build up in the root zone.

The adopted design approach was an integrated water management approach where both irrigation and drainage operations were collectively considered. The SIB9 drainage unit of Fourth Drainage Project (FDP) was selected for detailed investigation of the drainage operations. A transient model approach was adopted that takes into account temporal variations in recharge rate under the influence of crop. The water flow and solute transport model, SWAP was used to study the performance of drainage operations on crop transpiration, soil salinity and ground water table behavior over a period of 10 years. Overall, 13 different design combinations were tested including the present design

working at the FDP (W = 2.15, S = 515 m) and other design combinations of W = 1.5, 1.75, and 2.0 m for S = 200, 300, 400 and 500 m. The economics of the tested design combinations was also accounted for by working out the construction cost of the system. Drainage performance of different design combinations and the cost of the system was considered to select an optimum drainage design solution. Two design combinations were particularly tested to evaluate the feasibility of low cost drainage design combinations (shallow depth and wider spacing) incorporating farmers response to irrigation and drainage operations (no irrigation after a crop fails due to excessive wetness) and with managing irrigation operations(delaying irrigation application if watertable is shallower than 1.0 m).

The model was calibrated using the field measured data for a period of 01.06.91 to 31.5.94 for field No. 39/13N at SIB9 area of the FDP. Upper boundary conditions of the system were described by reference evapotranspiration rate, irrigation and rainfall and zero flux was defined as bottom boundary. Initial moisture conditions were described by equilibrium with the ground watertable. A 480 cm soil profile was divided into three layers. The soil water retention and hydraulic conductivity curves for these three layers were defined by Van Genuchten-Maulem (VGM) model. Model calibration was done by comparing field measured data of pressure head, soil moisture content and soil salinity with the model calculated data. Model parameters were adjusted to obtain a good agreement between the field measured and model calculated values.

The long-term impact of drainage operations with all tested design combinations clearly demonstrated that there would be no salinity hazard under the present cultural practices even without managing irrigation operations due to sufficient leaching of salts from precipitation and irrigation applications. The tested design combinations offered favorable soil and water conditions for the crops grown during the study period.

With the present cultural practices, drainage performance in terms of relative transpiration of the crop was achieved at its optimum level at 1.5 m drain depth with 200 and 300 m drain spacing, at 1.75 m drain depth with 200, 300 and 400 m drain spacing and at 2.0 m drain depth with 200, 300, 400 and 500 m drain spacing. The drainage design of 1.5 m drain depth with 400 or 500 m spacing and 1.75 m drain depth with 500 m spacing would not provide satisfactory drainage of the rootzone under usual irrigation practices (10 – 12 irrigation events per year) leading to complete crop failure due to excessive wetness.

Drainage performance of different design alterations and combinations also indicate that drainage out flows increases slightly with increasing drain depth. Deep watertable resulting from deeper drains provide lesser chances for sub irrigation i.e. the crop to draw its crop water requirement from the groundwater. The sub irrigation component for 1.5 m drain depth with 300m drain spacing is 0.015 mm/day greater in comparison to 2 m drain depth. The fulfillment of partial irrigation requirement from the groundwater through sub-irrigation and lesser amount of drainage outflow for shallow drains advocate the adoption of shallow drains, e.g. 1.5 m drain depth. This is also in line with the ultimate objective of the integrated water management approach where irrigation and drainage operations are jointly adopted to combat waterlogging and salinity.

The cost of the system was significantly affected by drain spacing but there was minimal effect of drain depth on the cost. The cost of the system decreased with the increased spacing between the drains. This advocated the selection of wider spacing. Therefore for environmentally and economically sustainable drainage system, it favors the choice of shallow and widely spaced drains (e.g. W = 2.0 m and S = 500 m). With the usual farmers practices and rainfall pattern, the design combination of 2.0 m drain depth with 500 m drain spacing provided the required drainage in relation to soil, plant and water conditions as well as lower construction costs.

Although a spacing of 500 m with 1.5 m drain depth resulted in unsatisfactory conditions under normal irrigation practices, the situation was improved by applying farmers likely response of no irrigation under conditions of prolonged root zone wetting or crop failure. This practice resulted in 80% and 70% crop success rate for drain spacing of 400 and 500 m respectively. With management of irrigation operations in terms of delaying irrigation applications for one or more weeks for conditions of watertable depth being less than 1 m, the crop success rate of 100% could be assured for 1.5 m drain depth and as much as 500 m drain spacing. This also results in marginally reducing irrigation applications and drainage outflows.

The study recommends that before applying steady state drainage design approach, it must be evaluated for its performance on long term rainfall and irrigation recharge patterns. Irrigation management options may also be evaluated to economize drainage design. Drains may be installed at as shallow and be as widely spaced as practicable to eliminate over-drainage, increase sub-irrigation component and decrease drainage outflows. Irrigation management may be adopted to eliminate crop stresses due to under or over drainage. This results in lower system costs.