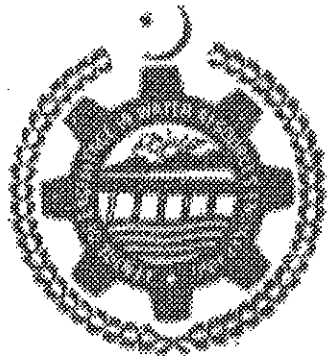
THESIS

SUITABILITY OF SHALLOW SKIMMING WELLS FOR SUSTAINABLE GROUNDWATER MANAGEMENT IN THE LOWER INDUS BASIN OF PAKISTAN



For the Degree of

MASTER OF SCIENCE

IN

WATER RESOURCES MANAGEMENT

BY

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ABSTRACT

The native groundwater in the Lower Indus Basin is of marine origin. Seepage from conveyance system, deep percolation from field irrigation and precipitation has formed fresh water layers of varying thicknesses floating over deeper saline groundwater. The indiscriminate abstraction of these relatively thin layers of fresh groundwater is causing upconing of underlying saline water and, hence, pumpage of poor quality groundwater resulting in secondary salinization of productive agricultural lands. Sustainable groundwater development of such shallow fresh groundwater layers requires careful thinking in design, operation and management of irrigation wells keeping in view the aquifer properties of the area. The prime objective of this study was to evaluate the hydraulics and solute transport mechanism under single and multi-strainer skimming well configurations.

Three dimensional finite difference groundwater flow (MODFLOW) and solute transport model (MT3D) were used to achieve the objectives of this study. Data regarding aquifer characterization, watertable elevations and pumped water quality for a double-strainer well located at Haroon farm, Khairpur was used to calibrate and verify the flow and transport models. A total of 41 pumping scenarios were formulated to evaluate the performance of skimming well. A number of well design and aquifer parameters were evaluated through sensitivity analysis to find out their impacts on quality of pumped water and upconing of underlying saline water. Various configurations of multistrainer skimming wells were also evaluated to optimize the number of strainers to abstract better quality groundwater.

The results indicated that for a shallow fresh water layer, salinity of pumped water increased linearly with pumping time. The rise in salinity was more pronounced for a higher well discharge and/or greater well operational factor. Although, the drawdown in the well achieved steady state condition within 0.75 day but the quality of pumped water continued to deteriorate. The rise of saline water mound also never stopped, instead it kept rising with time. The study revealed that in the aquifers where salinity difference of fresh and saline water is small, upconing not only occurs at a rapid rate but also to a greater height. Furthermore, it was observed that in case when the saline water cone had already intruded the fresh aquifer, any reduction in well discharge could neither ensure salt free water supply nor any fall in the already raised saline water mound could be observed, instead they kept rising on but at a sluggish rate.

Unlike the common belief and field observations, intermittent pumping could neither control the upward movement of interface nor any improvement in quality of pumped water be observed, instead they remained more or less stagnant. Such contrast in the results of this study is mainly attributed to the fact that MODFLOW/MT3D models do not take into account the density of fresh and saline water, which is an important parameter in suppressing the upconing. Therefore, it was believed that the models tend to over-estimate the solute movement and quality of pumped water. Modification is suggested to be incorporated in MODFLOW/MT3D programs.

During the sensitivity analyses of various design and aquifer parameters it was found that the pumped water quality deteriorated with increase in well discharge and operational factor, vertical hydraulic conductivity and longitudinal as well as transverse dispersivity.

Increase in fresh water cushion below well screen, horizontal hydraulic conductivity and effective porosity, on the other hand, resulted in improvement of pumped water quality. Greater sensitivity of all parameters was recorded at their smaller values. Vertical anisotropy ratio (K_h/K_v) was found to be the most dominant factor affecting quality of pumped water and/or upconing followed by fresh water thickness below well screen, well discharge and operational factor, effective porosity and longitudinal as well as transverse dispersivity. The effect of recharge was found negligible.

The study revealed withdrawal of better quality groundwater through multiple wells but no any direct relation between quality of pumped water and number of strainers was found. Unlike the other studies and common belief, this study, however, revealed greater upconing under multiple wells than under single-strainer well. The extent of upconing initially increased with number of strainers but as the pumping continued, it became similar. The upconing also became similar with increase in depth from the ground surface.

The four-strainer well proved to be the most promising among the six configurations investigated. In terms of pumped water quality, it ensured 15 -23 % improvement over single-strainer well and 3.4 to 9.1 % over double-strainer well. The improvement over double-strainer well increased with pumping time. Moreover, it resulted in limited upconing as compared to 3, 5 and 6-strainer wells.