Impact of Number of Well Points of Skimming Well on the Saline-Fresh Water Interface

S.H.M. Jaffery, A. B Sufi and M.M. Alam

Abstract

Pumping of groundwater for domestic industrial and agricultural uses has been constrained in many parts of the world by the encroachment of saline groundwater in response to fresh water withdrawals. Pakistan is no exception to it. Pakistan being an agricultural country is facing shortage of irrigation supplies to fulfill the crop water requirements, even after the conjunctive use of groundwater resources. Link canals and the irrigation network is associated with the seepage losses and poor drainage has resulted in the form of waterlogging and salinity in the entire Indus Basin. Rafique (1990) reported that in Pakistan 1.47 million hectares (mha) area has a water table within 1.5 m from the surface. Out of this 0.13 mha is covered by severely saline, uncultivated soils. In non-saline soils 0.32 mha have water table at 1.0-1.5 m, 0.28 mha at 0.5-1.0 m depth and 0.74 mha within 0.5 m. By the end of dry season, 13% of irrigated land has water table of less than 1.5 m. However, after the monsoon, 26% of the irrigated area has the water table of less than 1.5 m (Qureshi and Barrett-Lennard, 1998). The seepage water from the canals/reservoirs, if trapped and pumped before mixing with the under ground saline water, could be used for irrigation purposes and the problems of waterlogging and salinity could be minimized. This could be accomplished by using skimming well technologies. Thus the disruption in the groundwater regimes due to seepage from the extensive water distribution system could be controlled successfully.

However, a thin layer of fresh water exists in the Indus Basin near the recharge sources. To exploit thin fresh water layer to supplement deficit irrigation supplies is very essential for the salinity management in the crop root zone. For this purpose, fractional skimming well techniques could help us in benefiting from this resource with minimum disturbance of saline water. Keeping in view the importance, Mona Reclamation Experimental Project, WAPDA, Bhalwal is testing multi-strainer fractional skimming technique in the field. In this paper the trend of water quality of this skimming technique is presented. It concludes that water quality can be improved by increasing the number of well points. There is need to confirm the results further by testing more skimming wells at the farmers fields.

INTRODUCTION

Pakistan has an area of about 81 mha, over 21 mha of which is cultivated land. Out of 17 mha of total irrigated area, 12 mha land is irrigated by canals and the rest is served by other means such as tubewells, wells, tanks, springs and karezes (Statistical Survey, 1992-93). The irrigated area has a network of thousands of kilometers of canals and ditches to supply irrigation water to the farmers. As canal irrigation always involves diversion and redistribution of surface supplies, disruption of the hydraulic regime in the Indus plain was, therefore, inevitable (Sufi and Javed, 1988). Thus, seepage from the extensive water conveyance and distribution system, as well as deep percolation from precipitation and irrigation, has produced a high water table in the underlying alluvial aquifer over the years in many areas. The rise in the water table has triggered wide spread problems of waterlogging and salinity. As a consequence, extensive facilities for drainage and reclamation became unavoidable.

The problem of drainage is complicated by the fact that the native groundwater that existed in the pre-irrigation period was saline because of the underlying geologic formation being of marine origin. This is now overlain by a fresh water zone as a result of seepage between the native pre-irrigation water table and existing water table. However, in some areas, the thickness of the shallow groundwater zone ranges from less than 60 meters along the margins of doabs (area enclosed between two rivers) to 30 meters or more in the lower or central parts of doabs (Sufi and Javed, 1988). In such areas, private and public tubewells are likely to draw a substantial portion of their discharge from the saline zone unless special care is taken. Hafeez et al. (1986) reported that the pumped water in the shallow fresh groundwater zone has become more saline with time and many of the deep tubewells were shutdown at the request of farmers. It has been estimated that nearly 200 billion cubic meters of fresh water is lying on saline groundwater mostly in the form of a thin layer (Sufi et al., 1992). Obviously, if proper technology is applied, the referred thin fresh water layer can be skimmed from the aquifer with minimum disturbance of the saline zone. In the short-supply environment of Pakistan, such extractions would become a significant part of supplemental irrigation.

Private sector is showing great interest in the exploitation of pumping technology in Pakistan. However, tubewells are being installed even in the thin fresh groundwater zones with discharge rates from 28 to 45 l/s. If such tubewells are not replaced with fractional skimming wells, there is a serious concern that the water pumped will become increasingly more saline with time and many tubewells will have to be abandoned. As a matter of fact, in the Mona Reclamation Experimental Project (MREP) many large public wells (discharges 70-120 l/s) had to be closed on the request of farmers. Laboratory analysis also showed that these tubewells were pumping highly saline water as indicted in Table-1. Therefore, it seems imperative to introduce skimming well technology to address the future water quality concerns. For thin-layered fresh-water zones underlain by saline groundwater, low capacity fractional wells (discharge rates 6 to 9 l/s) have been and are being tried in the Mona Reclamation Experimental Project (MREP) to avoid the eventual pumping of saline water from the groundwater reservoir. These interventions are being tried under the research component of the World Bank funded National Drainage

Programme (NDP). The NDP has assigned a study titled "Root Zone Salinity Management using Fractional Skimming Wells with Pressurized Irrigation". Mona Reclamation Experimental Project (MREP) is executing the study with the partnership of IIMI-Pakistan. The main objectives of the study are given in the following section.

OBJECTIVES

General

1. To identify and test a limited number of promising skimming well techniques in the shallow fresh-water aquifers which could control the saline water upconing.
2. To encourage and support in-country manufacturers to develop low-cost fractional skimming well adaptable within the local setting of Pakistan; and
3. To implement an irrigation scheduling program aimed at root-zone salinity management with skimmed fresh (in a relative sense) water applied by low-cost pressurized systems.

Specific

This paper is a part of the input, which contributes towards the main objectives of the study. The specific objective of the intervention elaborated in this paper is to evaluate the effect of number of well points on the water quality of the effluent pumped out from the skimming well.

REVIEW OF LITERATURE

Bennett et al. (1968) and Sufi (1987) concluded that 15 percent well penetration gave maximum fresh water discharge over a stable brine cone, considering the pumping watertable as a horizontal line. McWhorter (1980) recommended safe well penetration limited to 30 percent. MacDonald and Partners (1984) observed that economical fresh water discharge can be achieved with deeper penetrations. Sufi et. al., (1998) used numerical model to simulate saline groundwater flow under various configurations of skimming wells. Their studies revealed that relative performance of recirculation well is better than single and compound wells. The study showed significant potential in improving sustainability of irrigated agriculture. Sufi and Javed (1988) made a review and remarked that shallow multiple skimming wells designed on the basis of immiscible theory would be successful if the fresh water layer was thicker than 30 meters.

Skimming well research was carried out under the Water Management Research Project, supported by the U.S. Agency for International Development (USAID) through the Engineering Research Center of Colorado State University (Sahni 1972, McWhorter, 1980). This work included laboratory experiments using immiscible fluids in a hydraulic model consisting of glass. Wang (1965) obtained well penetration ratio of 30 to 40 percent for critical discharge after which the fresh saline water interface became unstable. There was no specific literature found to be cited to evaluate the impact of number of well points on the quality of pumped water of skimming wells.

MATERIALS AND METHODS

Farmers were the main focus of the skimming well technique, their existing practices, their management skills, and capacity to accept and adapt the technology. The essential elements of the proposed strategy were: (i) joint learning and joint actions; (ii) participatory appraisal and design; (iii) participatory implementation; and (iv) participatory monitoring and evaluation. A detailed participatory rural appraisal and diagnostic analysis forms the basis for designing and implementing the project interventions so that these could be owned, operated and maintained by the farmers. This requires the selection of interested farmers instead of a contiguous target area. A brief summary of the start-up actions are described as below:

Rapid Rural Appraisal

An interdisciplinary team visited the Mona project area and conducted participatory rural appraisals jointly with the farmers who were found interested in the project. The farmers worked in the appraisal as equal partners. A checklist was designed for this activity. Informal dialogue and appraisal tools provided the methodologies for undertaking this exercise. The farmers were involved in data-collection and analysis so that their perceptions regarding problems and development of the solutions could be documented. Entry points were identified and the roles and responsibilities of all actors were clearly spelled out. The farmers were treated as advisors who were made responsible for the ranking of problems and their solutions. The appraisal was presented to the farmers for their final approval and consent to implement selected packages of technology and its management.

Diagnostic Analysis

The diagnostic analysis of individual farms was carried out by a joint team of Mona Reclamation Experimental Project (MREP) and Water Resource Research Institute (WRRI) with technical assistance provided by IIMI. This joint team documented sources and causes of low productivity and inefficient use of water in the area. The availability of water, existing water use, water table, soil and water salinity, cropping pattern, cropping intensity, etc. were measured/calculated at the farms of the participating farmers. The potential of the improvements will be matched with the intervention identified in the appraisal to develop a final outline of the potential innovations to be implemented under the project.

Surveys and Mapping

A topographic and profile survey of each selected farm was conducted. These surveys included: (i) the layout of irrigation channels and fields; and (ii) location of the tubewell, on-farm reservoir, or other salient features at the farm. The survey data was mapped. The hydrological, chemical and agricultural information were incorporated on the survey maps. Also, at the farms of interested farmers, information about suitable location(s) for skimming wells were also based on water quality monitored at incremental depths by digging bore holes. Based on the outcome of the approach stated above, a clear-cut scheme of limited treatment was finalized. The final decision on the selected treatments was made in consultation with ILRI Advisor.

Multi-Strainer Skimming Well

A multi-strainer skimming well was selected at Chak No. 1/NB near Phularwan, Bhalwal in the vicinity of the Northern Branch Canal at farmers field. The well had initially four well points designated as well A, B, C and D. Two additional well points were also installed with the well having already four well points. These points are designated as well E and F. Configuration of the well points is shown in Figure 1. To investigate the saline interface, and to observe the effect of pumping on the watertable depth and on the quality of groundwater deep observation wells up to 30 m depth were installed in series near the skimming well and data was collected. Movement of the interface was observed under controlled conditions of pumping. An observation well was also installed to monitor the watertable. The water and soil analysis was carried out at the MREP Laboratory.

RESULTS AND DISCUSSIONS

Results of water analysis from the existing four well points configuration are presented in Table 2. Average water quality of well was found 951 ppm TDS. After installation of two additional well points, water samples were again collected and analysed (Table 3). The table indicates the average quality of water under increased well points in the range of 766 ppm. Review of data presented in Table-2 and 3 indicates that water quality of the skimming well was improved with the increased well points. Comparative average of water quality under both conditions is shown in Figure 2. This gave the indication that increased well points can possibly help in reducing the upconing of saline water. However, it is obvious that increasing well points have direct relationship with the installation cost of the skimming well. Such analysis was not done. These results hint toward the reasonable tradeoff between the installation cost of the skimming well and anticipated quality of the water to be pumped It suggests adoption of cropping patterns and the types of crops to be grown with particular reference to the intended well points and resulting water quality of the skimming wells. Soil salinity and soil physical analysis of the samples collected from the skimming well location was also carried out. The results are presented in Table 4 and 5 respectively. These results indicate that soils have high pH value whereas, topsoil is silty clay loam underlain by predominantly sandy strata.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions were drawn from the data analysis presented in the paper.

1. Increase in the well points can possibly improve the water quality of the skimming wells.
2. Cost of installation of skimming wells can increase with the increase of well points.

Recommendations

The following recommendations can be made for the further study to confirm the results and develop a recommendable tradeoff between number of well points and improvement in water quality.

1. It is recommended to establish the relationship between well configuration/ number of well points and its impact on water quality.
2. Detailed economic analysis is recommended to evaluate the impact of skimming well technology.
3. A suitable cropping pattern and type of crops may be adopted with respect to water quality of skimming wells.

REFERENCES

Bennett, G. D., M.J. Mundorff and S.A. Hussain. (1968) Electric analog studies of brine coning beneath fresh water wells in the Punjab region, West Pakistan, Geological Survey Water Supply Paper 1608-J.

Hafeez, A., Z.A. Piracha and N. Ahmed. (1986) Multi-strainer tubewells for skimming top layer of fresh water underlain by saline water in the aquifer, Mona Reclamation Experimental Project, WAPDA.

Sufi, A.B., (1987) Electric analog studies of fresh water skimming, Centre of Excellence in Water Resources Engineering, University of Engineering and Technology, Lahore.

Sufi, A.B. and S.M. Javed (1988) Review of existing research on skimming wells, Publication No. 3, International Waterlogging and Salinity Research Institute, Lahore.

MacDonald. Sir M., and Partners Limited (1984) South Rohri fresh groundwater project: Final design review report, Water and Power Development Authority, Lahore.

Sufi, A.B., H. Yawar and F.A. Zuberi (1992) Review of design criteria for proper design of skimming wells, Proceedings of ICID 5th International Drainage Workshop, February, 1992, Lahore, #: 3.30-3.42.

McWhorter, D.B. (1980). Summary of skimming well investigations, Water Management Technical Report No. 63.

Wang, F.C., (1965) Approximate theory for skimming well formulation in the Indus plain of West Pakistan, Journal of Geophysical Research, 70(20):5055-5063.

Sahni B.M., (1972) Saltwater coning beneath fresh water wells, WMTR. No. 18. CSU, Colorado, USA.

Sufi, A.B., M. Latif and M. Akram (1998). Modeling of Different Skimming Wells Configurations for Relatively Fresh Groundwater Exploitation. Journal of Drainage and Water Management. Volume 2, No.1, January – June, 1998.

Table I. Water quality data of abandoned deep wells at MREP.

Tube Well No.	TDS (ppm)	SAR	RSC (meL-1)
MN 116	3520	23.3	2.23
SHP-20	6080	36.0	-
MN 138	3006	10.1	-
MN 93	1408	12.0	4.10
MN-80	1910	17.0	8.00
MN 37	2240	15.1	4.10

Table 2 Water quality of existing skimming well having four well points.

Sample. No.	TDS (ppm)	pH	SAR	RSC (Meq/l)
1	1114	7.6	4.55	-
2	826	7.8	5.46	2.0
3	819	8.2	11.58	3.6
4	890	8.0	11.90	3.7
5	954	7.8	8.04	2.0
6	1005	7.6	8.62	2.0
7	870	7.9	8.69	2.2
8	1126	8.0	9.24	1.5
Average	951	7.9	8.51	2.13

Table 3. Water quality of skimming well with two additional well points

Sample No.	TDS ppm	pH	SAR	RSC (Meq/l)
1	768	7.7	10.73	3.9
2	770	7.7	10.03	3.4
3	762	7.8	9.23	3.1
4	765	7.8	7.76	2.4
5	764	7.8	10.67	3.2
6	765	7.8	9.96	3.3
Average	766	7.8	9.73	3.2

Table 4. Soil salinity analysis.

Depth (cm)	pH	ECe (dS/m)	SAR
00 - 10	8.2	1.1	5.0
10 - 20	8.5	0.8	3.4
20 - 30	8.8	0.8	6.0
30 - 40	8.9	0.8	7.5
40 - 50	8.9	0.6	4.0
50 - 60	8.8	0.7	5.0
60 - 70	8.7	0.8	4.9
70 - 80	8.8	0.8	7.5
80 - 90	8.7	0.7	6.3

Table 5. Soil Physical Analysis

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class
0-10	18	53	29	Silt Clay Loam
10-20	92	5	3	Sand
20-30	94	5	1	"
30-40	96	3	1	"
40-50	94	5	1	"
50-60	94	5	1	Sand
60-70	80	9	11	Sandy Loam
70-80	96	3	1	Sand
80-90	94	5	1	"

Multi strainer skimming well layout at Phularwan Chak No. 1 NB.

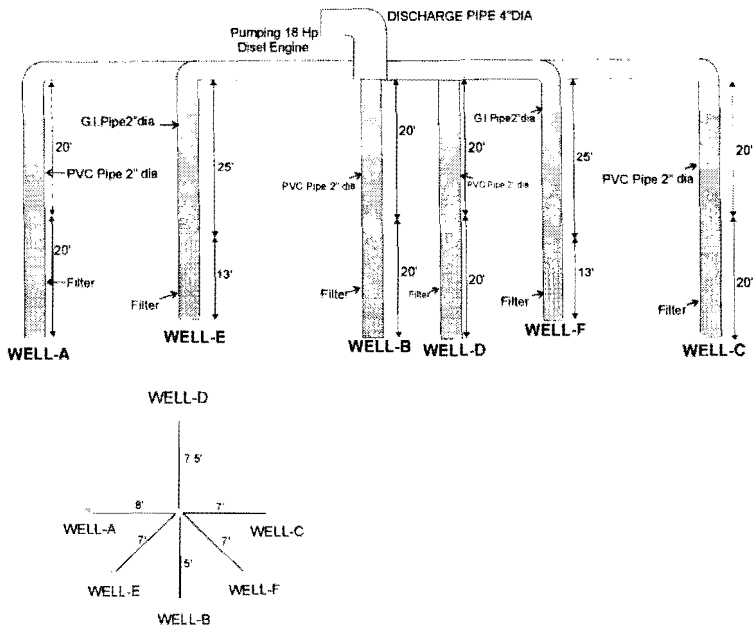

Figure 1. Schematic configuration of the multi-strainer skimming well.

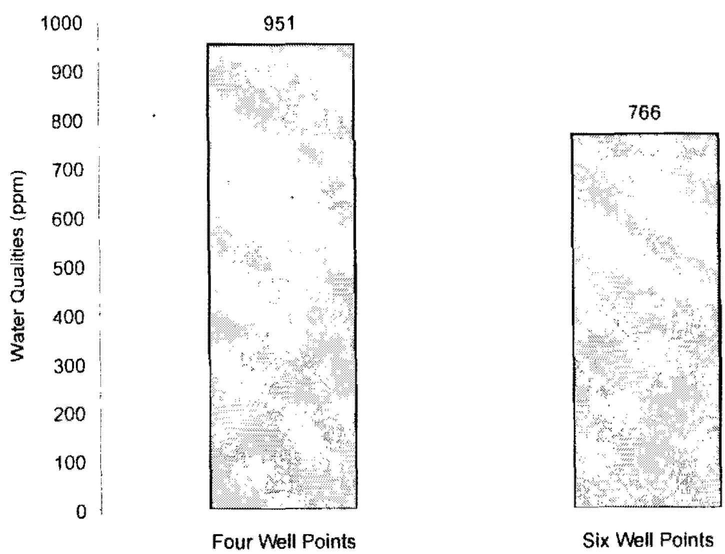

Figure 2. Comparative Water Quality of Various Skimming Well configration.