ASSESSMENT OF HYDRO-GEOLOGICAL POTENTIAL OF SKIMMING WELLS IN THE LOWER INDUS BASIN OF PAKISTAN

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For disseminating the findings of Root Zone Salinity Management Project to the farming community in the Lower Indus Basin, the International Water Management Institute (IWMI) conducted a project on *Assessment of Hydro-Geological Potential of Skimming Wells in the Lower Indus Basin of Pakistan*. This project was started in July 2004 and concluded in December 2004. The National Drainage Program (NDP), Research Component – WAPDA funded this project. In this project, the areas where skimming well technology can successfully be applied in the Lower Indus Basin were delineated. A comprehensive evaluation of the existing shallow tubewells practices was also conducted. Two field demonstration sites were established where skimming wells were installed for supplying groundwater to the drip irrigation system for *bair* orchards. Farmers were then introduced to these systems through farmers' days and field workshops. The project-end workshop featured not only the farmers but also the provincial policymakers and research community. The primary beneficiaries of this project are the farmers depending currently on unsustainable water use patterns. The adoption of such systems will not only solve environmental constraints, but also provide on demand availability of good quality irrigation water. If government encourages the adoption of skimming well source pressurized irrigation systems, then it would help in increasing crop productivity and improving farmers' livelihood resulting from sustainable conjunctive water use of canal and skimmed groundwater resources.

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Assessment of hydro-geological potential of skimming wells in the lower Indus basin of Pakistan

Summary

This report provides a comprehensive overview of the activities and their findings targeted to achieve the objectives of the project entitled, "Assessment of Hydro-Geological Potential of Skimming Wells in the Lower Indus Basin of Pakistan".

For disseminating the findings of Root Zone Salinity Management Project to the farming community in the Lower Indus Basin, the International Water Management Institute (IWMI) conducted this project from July 2004 till December 2004. The National Drainage Program (NDP), Research Component – WAPDA funded this project.

In this project, the areas where skimming well technology can successfully be applied in the Lower Indus Basin were delineated. A comprehensive evaluation of the existing shallow tubewells practices was also conducted. Two field demonstration sites were established where skimming wells were installed for supplying groundwater to the drip irrigation system for *bair* orchards. Farmers were then introduced to these systems through farmers' days and field workshops. The project-end workshop featured not only the farmers but also the provincial policymakers and research community.

Based on project activities and their findings, the following conclusions can be drawn:

- The Meander Plain represents soil type responsible for forming fresh groundwater lenses through recharge overlain by native saline groundwater layers. Figure 9 presents the potential areas for skimming wells in different canal commands of the Lower Indus Basin.
- Resistivity Survey (RS) provides a quick and effective mean to ascertain the sub-surface hydro-geological conditions in terms of groundwater quality and the nature of sub-surface materials for the selection of prospective locations for the development of fresh groundwater through the installation of tubewells.
- Majority of the farmers showed interest and trust in this skimming well source drip irrigation system to address their canal water scarcity and groundwater quality constraints. Minority of the farmers believed in 'seeing and believing'; field demonstration sites and adoption of such systems by their fallow farmers would help in motivating these farmers. Only a few farmers showed reluctance, simply due to high installation cost and sophistication. Public-private partnership could help to address their concerns.
- The installation of skimming wells will generate economic activity in saline groundwater areas, where at present groundwater extraction technology is not present. The local pump and related equipments manufacturing industry –to be used in skimming well installation, as well as, the local well drillers and rural laborers –to be engaged in skimming well installation, will benefit from this economic activity. This promisingly cost-effective technology will help

poor farmers to install and operate their own wells –thereby improving equity of benefits from groundwater irrigation among the farming community.

- Accurate estimation of groundwater potential, in both the saline groundwater as well as in fresh groundwater areas, will help policymakers and water sector planners to evolve consensus on the sustainable, productive and equitable distribution of canal water resources. This will ensure long-term sustainability of irrigated agriculture in the Indus Basin of Pakistan.
- The ultimate impact of adopting properly designed and operated skimming wells will be on the entire community through increased food security and environmental sustainability. Improved agricultural production through access to groundwater in saline groundwater areas will provide more income to the farmers that will help in improving their livelihoods and reducing poverty. Increased agricultural productivity will also contribute to the national economy.
- The two major environmental problems of the Lower Indus Basin are deteriorating groundwater quality and increasing salinization of agricultural lands. The pumping of large volumes of groundwater from relatively fresh groundwater areas is causing intrusion of saline groundwater into fresh groundwater areas thereby degrading the aquifer. The extensive use of poor quality groundwater for irrigation is adding huge amounts of salts in the root zone, which is aggravating the problem of soil salinity. The project addressed both these environmental issues. Skimming well technology helped in extracting maximum volume of groundwater without occurring saline groundwater upconing and groundwater quality deterioration. The application of this skimmed groundwater using drip irrigation system would help in maintaining productive capacity of the root zone by overcoming problems of soil salinization. Therefore, the successful adoption of these interventions would preserve the resource and will have a positive impact on the environment.
- Water quality parameters responsible for making the water samples marginal were: (i) TDS for Tehsil Hyderabad, Tando Allah Yar and Hala, (ii) TDS and RSC for Tehsil Tando Muhammad Khan and (iii) SAR+RSC for Tehsil Matiari. However, for most of the marginal samples, SAR was not so high to create any considerable problem.
- In whole Hyderabad district, TDS and RSC are causing most of the tubewells water to be Hazardous for irrigation purposes. All other parameter such as, SAR, EC+SAR, EC+RSC, SAR+RSC and EC+SAR+RSC have negligible role to make the pumped water hazardous for irrigation purposes.

It is recommended to:

- The primary beneficiaries of this research are over 3 million farmers of the Indus Basin who are largely depending on unsustainable water use patterns to meet their crop water

requirements. The adoption of such systems will not only solve environmental constraints, but also provide on demand availability of good quality irrigation water. If government encourages the adoption of skimming well source pressurized irrigation systems, then it would help in increasing crop productivity and improving farmers' livelihood resulting from sustainable conjunctive water use of canal and skimmed groundwater resources.

- The project generated practical scientific knowledge about how to design and operate skimming wells for sustainable extraction of groundwater in the Indus Basin. This problem-solving framework will benefit scientists and intellectual community who will have an increased insight into the processes and practices of skimming wells. The generated scientific knowledge will be equally applicable in other countries, for instance in India, Uzbekistan, Iran, China, and Egypt, facing similar groundwater management issues.
- Most of the tubewells are having shallow depths. Farmers are aware off the thin fresh groundwater lenses overlying the saline groundwater layers a prerequisite for installing skimming wells. The quality of pumped water being marginal and hazardous for irrigation purposes showed that the saline groundwater upconing occurred in these tubewells –this upconing could be avoided using skimming wells.

Introduction

In the Indus basin of Pakistan, groundwater has contributed substantially to food security by providing water-on-demand to a large majority of farmers. The private tubewells in the Indus basin has increased from 3,000 in 1950 to over 600,000 in 2000, and at present over 3 million farmers are directly or indirectly dependent on groundwater to meet their irrigation requirements. The current rate of groundwater use has exhausted the aquifers in fresh groundwater areas and there is very little scope for further groundwater development. However, some estimates show that about 200 BCM of water is stored in thin fresh groundwater lenses in the saline groundwater areas of the basin. These saline groundwater areas cover about 22 and 78 percent of the Indus Basin component in Punjab and Sindh, respectively.

More than 80 percent of saline groundwater areas in Punjab, and 50 percent in Sindh have fresh groundwater lenses that can be exploited using skimming wells. Farmers in these areas have already installed nearly 10,000 skimming wells. But many of these wells often have problems of deteriorating water quality due to inadequate design and poor operational strategies. Furthermore, groundwater use is undertaken without full awareness of the hazard presented by the water quality. As a result salt-affected soils have become an important ecological problem in the Indus Basin in general, with nearly six Mha of the irrigated area already severely afflicted by soil salinity, and in the Lower Indus Basin in particular. Thus, while groundwater represents a valuable resource for irrigation to help alleviate poverty, any gains may be short-lived without an integrated approach to identify potential solutions for the groundwater management problems.

Figure 2 shows the canal command areas in the Lower Indus Basin. Rohri, Dadu, Ghotki, Khairpur East Feeder and Khairpur West Feeder are the five main canals of the Lower Indus Basin. The Rohri canal, which is the heart line of the irrigated agriculture in Sindh, off-takes from left bank of Sukkur barrage. The canal has six major branch canals, including Dad, Nasrat, Ali Bahar, Hala, Nasir and Tando Adam. The full canal capacity of Rohri canal is 10987 cusec (310.9 cumec). The canal supplies 2.6 million acres CCA. The Dadu canal is a perennial canal off-taking from the right bank of Sukkur barrage with a full supply capacity of 3150 cusec (89.1 cumec) for a total CCA of 0.55 million acres. The Ghotki canal, which is also perennial canal, off-takes from left bank of Guddu barrage, running in parallel to the protection band of Indus River. Its full capacity is 8490 cusec (240 cumec) for a command area of 0.9 million acres, mainly including Ghotki and Sukkur districts. The Khairpur Feeder East off-takes from left bank of Sukkur barrage with full supply discharge of 1938 cusec (54.84 cumec). Its command area is 0.5 million acres. This perennial canal irrigates middle and eastern parts of Khairpur districts. The Khairpur West Feeder off-takes from left bank of Sukkur barrage with full capacity of 1940 cusec (54.9 cumec) with two larger branches, Abdul Wah and Faiz Wah. This perennial canal irrigates western parts of Khairpur district having a command area of 0.30 million acres.

The geo-hydrological characteristics of the Indus Basin aquifer vary substantially from place to place. Fine-grained deposits of low permeability generally are discontinuous so that sands making up to 65 to 75 percent of the alluvium serve as a unified highly transmissive aquifer. The thickness of the alluvium sediments has been reported to be in excess of 1000 m in Punjab, but as little as 100 m in Sindh. Other aquifer properties including: (i) average specific yield is about 13% in Sindh and 20% in Punjab, (ii) lateral hydraulic conductivity averages 4.3×10^{-3} m/sec in Sindh and 5.8×10^{-3} m/sec in Punjab, and (iii) average horizontal to vertical anisotropy rates vary between about 30:1 in Sindh and 50:1 in Punjab. Therefore, as a part of dissemination strategy, there is a need to implement in the Lower Indus Basin of Pakistan, the technologies and methodologies originally established elsewhere in the Indus Basin. Thus, this project was designed as such, so as the food security and livelihoods of rural communities can be protected through sustainable groundwater management in the Lower Indus Basin of Pakistan.

BACKGROUND AND JUSTIFICATION

Rainfall and canal water supplies are generally insufficient to meet crop water demands in the Indus basin and thus groundwater now contributes significantly to fill the gap between water demand and supply. In recent years, groundwater has contributed substantially to improved food security by providing water-on-demand to millions of farmers and now contributes over 50 percent of crop water requirements in the basin (ACE Halcrow JV Consultants, 2002). Although groundwater use has transformed agriculture from low and uncertain crop yields to more secure and predictable crop production, this is being done without full awareness of the hazard represented by groundwater quality.

Salt-affected soils have become an important ecological problem in the Indus Basin in general, with nearly six Mha of the irrigated area already afflicted by soil salinity, and in the Lower Indus Basin (LIB) in particular (Table 1). Out of these salt-affected soils, about 4.34 Mha are strongly salt-affected, 1.23 Mha are moderately salt-affected and 0.60 Mha are slightly salt-affected in nature (Table 2). The extent of lands impacted changes continuously due to dynamic nature of the problem. At present, only 14 percent of these salt-affected soils are salinized due to capillary rise from shallow water table, the balance being due to use of groundwater. Table 3 summarizes the province-wise breakdown of the existing groundwater resources and the present status of groundwater extractions in the Indus Basin of Pakistan. There remains a considerable potential for groundwater development. However, while developing resources for irrigation promises to help alleviate poverty; any gains may be short-lived unless appropriate strategies for sustainable use are adopted.

In the Indus Basin, the natural groundwater is deep and saline because of the marine origin of the hydro-geologic formation. Percolation of irrigation and rainfall waters has formed fresh groundwater lens in many locations above the underlying saline groundwater layer. The thickness of this fresh groundwater lens varies from a few meters to 150 m. In general the fresh groundwater areas are

found close to the rivers, and saline groundwater areas in the central and lower regions of the *doabs* –area enclosed between two rivers (Figure 1). In fresh groundwater areas, the fresh groundwater lenses are thick, usually greater than 38 meters. In saline groundwater areas, the thickness of fresh groundwater lenses is thin (i.e., less than or equal to 38 meters). “Don’t tamper with the dormant saline aquifer” should be the motto to be followed in these areas. Saline groundwater areas cover about 22 percent of the Indus Basin in Punjab, and 78 percent in Sindh. According to an estimate, about 200 BCM of water is stored in these thin fresh groundwater lenses in the saline groundwater areas of Punjab and Sindh. Development of appropriate technology and adequate operational strategies for the safe abstraction of this valuable resource can contribute significantly in overcoming the scarcity of water in the Indus Basin (Saeed et al., 2003).

Before the introduction of groundwater extraction technology, in the 1960’s, groundwater was considered a liability rather than an asset because of the waterlogging problems associated with high water tables. Since the inception of the SCARP –Salinity Control and Reclamation Projects, which implemented single-strainer deep tubewells, the utilization of groundwater for irrigation has grown rapidly. Farmers indigenized this technology as a single-strainer shallow tubewells in fresh groundwater areas, and small bore multi-strainer shallow tubewells, referred to as skimming wells, in saline groundwater areas of Punjab and Sindh. The number of tubewells has increased from about 3,000 in 1950 to over 600,000 in 2000. In Sindh, where waterlogged areas adversely affects over 38 percent (in 1999) of the irrigated areas, the introduction of farmers’ skimming wells to extract fresh groundwater has reduced the waterlogged areas by about 5 percent in 2000 (ACE Halcrow JV Consultants, 2003). Groundwater extraction by the private sector is greatly helping to reduce the problems of waterlogging and related soil salinization. However, the patterns of groundwater extraction are neither uniform nor well matched to the amount of recharge taking place in the area.

Whenever water is lifted from the shallow fresh water aquifers to the surface, and is used for crop production; plants extract the fresh water and leave the salts behind in the soil. If leaching does not occur, then salts build up in the soil and affect plant growth. If leaching occurs, these salts enter the top of the shallow fresh water aquifer and increase its salinity. This process of vertical recycling of salts will ultimately have a serious and lasting affect on groundwater quality in the aquifer. To date, no systematic studies have been conducted to evaluate the salt balance in the different irrigation commands of the Indus Basin. Adequate salt balances must be made to enable a vigilant eye to be kept on the salt flux being added to the irrigated soils. The location and number of tubewells, their pumping hours and average water chemistry, local cropping patterns, crops yield and water supplies will enable estimation of the salt balance. A spatial and temporally disaggregated database of these key variables will be useful at all stages of planning and operation of tubewells. However identification of potential solutions to the groundwater management problems will only be achieved through the adoption of a comprehensive and integrated approach.

Tables 4 and 5 summarize the area-wise distribution of groundwater qualities based on the composite groundwater quality in the 0 – 38 m (suitable for skimming wells) and 0 – 107 m (with respect to SCARP tubewells) profiles of the aquifer, respectively. More than 80 percent of saline groundwater areas in Punjab, and 50 percent in Sindh have fresh groundwater lenses that can be exploited using skimming wells. Farmers in these areas have already installed nearly 10,000 such wells –farmers' skimming wells (ACE Halcrow JV Consultants, 2002). However, many of these wells, especially those in the saline groundwater areas, are extracting groundwater from inappropriate depths and discharge rates, and above all, with inadequate operational schedules (Saeed et al., 2002), resulting in deteriorating quality of extracted water. A large number of wells have already been abandoned due to poor water quality. Properly designed and operated wells will be of great help to farmers in their search for adequate water resources.

Numerous efforts have previously been made to develop cost-effective and technically feasible skimming wells for safe extraction of groundwater from the saline groundwater areas. For example, during the 1970s the Mona Reclamation Experimental Project (MREP), in cooperation with Colorado State University, conducted research on skimming wells and found that often a safe yield of only 3 – 6 l/s could be obtained from these aquifers (Kemper et al., 1976). But, farmers require a minimum discharge of about 28 l/s to irrigate their fields using surface irrigation methods. Chandio and Chandio (1992), Mirbahar et al. (1997) and Sufi et al. (1998) reported that skimming wells are an effective way of controlling on-farm drainage because they can create a favorable check over the local hydrological balance. Skogerboe et al. (1999) compared skimming wells with subsurface horizontal drainage systems and showed that subsurface drainage is roughly one hundred times more costly than skimming wells. For this comparison, the volume of water to be pumped using skimming wells will correspond with the volume of water removed by subsurface drainage.

In March 1999, IWMI implemented a research project on "Root Zone Salinity Management Using Fractional Skimming Wells with Pressurized Irrigation" in the Punjab, Pakistan with two national collaborators funded by the National Drainage Program (NDP). The study was concluded in June 2003 having made considerable progress in identifying and testing a number of promising skimming well technologies to control saline groundwater intrusion as a consequence of pumping. Improved design parameters and operational management strategies for skimming wells were also identified (Asghar et al., 2002a). For the given hydro-geological and hydro-salinity conditions of aquifers in Chaj doab, 8 – 24 l/s can effectively be skimmed following the improved design parameters and operational management strategies for skimming wells (Asghar et al., 2002b). Our results also demonstrated a linear increase in discharge rate with the increase in number of strainers (5 cm diameter) from 1 to 4, and no further increase in discharge with additional strainers.

The results of the Root Zone Salinity Management Project were extensively discussed by over 100 participants at the project-end workshop held on June 26, 2003 in Islamabad and found that the

skimming wells technique as a tool for sustainable groundwater extraction would have a broad room to be extended in the country for better groundwater management. The participants stressed that the scope of the study should be extended to other parts of the Indus Basin, and the results disseminated to the wider farming community. To explore such application feasibility, the National Drainage Program (NDP) contracted IWMI Pakistan on this project. This project is the follow up of the earlier research study on skimming wells in Punjab and builds on the established technologies and methodologies for implementation and dissemination in the Lower Indus Basin of Pakistan.

PROJECT OBJECTIVES

In the Lower Indus Basin, groundwater aquifers are a mixture of fresh and saline water layers, given the marine aquifer origins, hydro-geologic formations, and limited rainwater but sizable irrigation percolation. Sustainable abstraction of valuable freshwater without disturbing the saline aquifer by using proper pumping technique represents a major challenge in Sindh water management. There are around 10,000 tubewells installed in Sindh. A large portion of them, however, is not in operation because of the saline quality of the water. Upward salt movement by groundwater pumping causes troubles for farmers in well water use. The skimming-well technique would find the best application in the province. However, do Sindh farmers welcome, and know, the technique, and what are needed guidance in field to extend the application? These are the questions behind the project design, and therefore, the project objectives are defined as:

- To delineate (and map using GIS-RS) areas suitable for skimming wells while estimating (spatially and temporally) the thickness of fresh groundwater lenses above the underlying native saline groundwater layers; and
- To understand farmers' perceptions regarding the social acceptability; economic viability; and potential for use of skimming wells in saline groundwater areas having different hydro-geological and hydro-salinity conditions.

PROJECT ASSUMPTIONS AND RISKS

For the proper execution of project activities to achieve the targeted outcomes, the following assumptions were made, and the related risks were identified while designing the project to minimize those risks:

- The main assumption is that the skimming wells will be widely adopted for extracting shallow and thin fresh groundwater lenses from the saline groundwater areas of Pakistan. To ensure this wider adoption of skimming wells in the Lower Indus Basin, the involvement of different stakeholders of skimming wells form an integral part the project formulation and implementation.

- The availability of the pumps and the related equipments in the local market is necessary to address the socio-economic concerns of the farmers in adopting skimming wells. The effective involvement of local manufacturers, well drillers and farmers in the project will help in achieving this objective.
- Timely availability of secondary data is a prerequisite for assessing the potential of skimming wells in the Indus Basin of Pakistan. IWMI's close collaboration with most of the data generating agencies such as WAPDA, PIDA's, and Soil Survey of Pakistan (SSP) will help in the smooth acquisition of data.
- Natural hazards like heavy rainfalls and floods will impede the fieldwork, and will impair the possible outcomes of the field research.

Table 1. Province-wise distribution of salt-affected soils (ACE Halcrow JV Consultants, 2003).

Province(s)	CCA (Mha)	Salt-affected areas (Mha)	Percentage of CCA
N.W.F.P.	0.296	0.05	17
Punjab	8.203	2.66	32
Sindh & Balochistan – the Lower Indus Basin	5.486	3.46	63
Total	13.985	6.17	44

Table 2. Classification of salt-affected soils in the Indus Basin of Pakistan (ACE Halcrow JV Consultants, 2003).

Classification of salt-affected soils	Area affected (Mha)	Characteristics
Slightly salt-affected	0.60	Slightly salinity and sodicity problem, occurring as patches (about 20% of the area) in cultivated areas.
Moderately salt-affected	1.23	Saline and sodic throughout the root zone, but is porous and pervious to water
Strongly salt-affected	4.34	1.96 Mha is salt-affected due to high water table, and is dense and nearly impervious to water. 2.38 Mha is salt-affected mainly due to application of sodic tubewell water, which contains high concentration of carbonates and bicarbonates. These areas are also almost impervious.
Total	6.17	

Table 3. Present groundwater resources, the present status of groundwater extraction, and the sustainable groundwater potential in the Indus Basin of Pakistan (ACE Halcrow JV Consultants, 2002).

Province(s)	Groundwater resources (BCM)	Existing uses –Year 2001 (BCM)	Gross surplus (BCM)
N.W.F.P.	3.8	2.5	1.3
Punjab	53.3	49.3	4.0
Sindh	22.7	9.2	13.5
Balochistan	2.6	1.0	1.6
Total	82.4	62.0	20.4

Table 4. Area-wise distribution of various groundwater qualities based on the composite groundwater quality in the upper 38m profile of the aquifer (ACE Halcrow JV Consultants, 2003).

Province(s)	CCA (Mha)	GCA (Mha)	Fresh areas (% of GCA)	Marginal areas (% of GCA)	Hazardous areas (% of GCA)
N.W.F.P.	0.296	0.400	87.6	12.4	
Punjab	8.203	9.842	77.6	9.8	12.6
Sindh & Balochistan	5.486	6.243	23.8	13.8	62.4
Total	13.985	16.485	57.4	11.4	31.2

Table 5. Area-wise distribution of various groundwater qualities based on the composite groundwater quality in the upper 107m profile of the aquifer (ACE Halcrow JV Consultants, 2003).

Province(s)	CCA (Mha)	GCA (Mha)	Fresh areas (% of GCA)	Marginal areas (% of GCA)	Hazardous areas (% of GCA)
N.W.F.P.	0.296	0.400	87.6	12.4	
Punjab	8.203	9.842	69.5	13.5	17.0
Sindh & Balochistan	5.486	6.243	15.1	8.8	76.1
Total	13.985	16.485	49.3	11.9	38.9

Figure 2. Spatial distribution of composite groundwater quality (0-107m depth) in the Indus Basin.

Figure 2. Spatial distributions of different canal command areas in the Lower Indus Basin.

GIS Mapping of Skimming Well Areas in the Lower Indus Basin

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INTRODUCTION

For assessing hydro-geological assessment of skimming wells in the Lower Indus Basin of Pakistan, the following activities were conducted:

- GIS database development,
- Use of GIS for groundwater quality mapping,
- Resistivity Surveys to verify groundwater quality at shallower depths,
- Diagnostic analysis by installing and monitoring observation wells for groundwater quality with depth monitoring to verify RS results, and
- GIS Mapping of areas having potential for installing skimming wells in the Lower Indus Basin.

GIS DATABASE DEVELOPMENT

Data from secondary resource was collected to develop GIS based database for the Lower Indus Basin. The data sources are given as under:

- Published in 1966 by WAPDA in the Lower Indus Reports, prepared by the Hunting Technical Services Ltd, and Sir M. MacDonald & Partners.
- Published in 1981 by WAPDA in the Soil Salinity Survey reports, prepared by the Survey and Research Organization, Planning Division, Lahore.
- Published SMO reports, prepared under the NDP funded project, on the pumped groundwater quality obtained from hand pump, shallow tubewells (private) and deep tubewells (public) installed in different canal commands of the Lower Indus Basin.

The GIS analysis results are presented in this report, however the GIS database developed under this study is also made available on request.

GIS GROUNDWATER QUALITY MAPPING

Using this database, the available information was reclassified in the form of GIS thematic layers for the whole LIB at different depths of the aquifer. Figure 1 and 2 presents spatial distribution of waterlogged and salinized areas in the Lower Indus Basin of Pakistan. It appears that the waterlogging and soil salinization are the two major environmental constraints of reducing crop productivity in the Lower Indus Basin of Pakistan. Soil salinization is not only due to waterlogging, but also because of soil lithological and groundwater use.

Using the secondary sources data, the spatial distribution of the composite groundwater quality in the aquifer between 0-37m and 0-107m profiles are shown in Figure 3 and 4, respectively. The deep groundwater quality map shows that the fresh groundwater is mainly concentrated around the Indus River, but the scope of extracting fresh groundwater is not wide spread in the whole Lower Indus Basin. However, when shallow groundwater quality is considered, the fresh groundwater occurrence appears to be more wide spread. Therefore, groundwater extraction technology like skimming well would play pivotal role in fulfilling the socio-economic and fresh water needs of the majority of the farming community.

Naturally, the groundwater in the Lower Indus Basin is of marine origin, therefore the occurrence of saline groundwater is likely phenomenon. However, due to recharges from field irrigation applications, irrigation network and rainfall have resulted in fresh groundwater lenses over these natural saline groundwater layers. GIS analysis is used to delineate areas that have fresh groundwater overlain by saline groundwater in the Lower Indus Basin. Figure 5 presents areas that have fresh groundwater (from Figure 3) underlain by marginal and hazardous groundwater (from Figure 4).

RESISTIVITY SURVEYS

Resistivity Survey (RS) was made on several sites in the Lower Indus Basin of Pakistan. The detailed of the results is presented in Appendix I. Table 1 presents the summary of these results.

Table 1. Summary of the resistivity survey results for various locations in the Lower Indus Basin.

Sr. No.	Location	Number of Surveys	Fresh Groundwater (m)
1	Chambar	2	5 – 60
2	Dadu	1	0
3	Golarchi	1	25
4	Jacobabad	1	15
5	Karachi	1	20
6	Khipro	1	0
7	Kunri	1	5
8	Mirpurkhas	8	0 – 15
9	Mirwah Gorchani	1	15
10	Nafees Nagar	1	0
11	Naukot	1	5 – 15
12	New Saeedabad / Saeedabad	4	40 – 150
13	Shaikh Barkio	1	20
14	Taluka Jam Nawaz Ali	1	15
15	Tando Adam	1	80
16	Tando Allah Yar	14	15 – 100
17	Tando Jam	1	0
18	Thatta	1	5 – 20

The RS was made to investigate groundwater quality at different depths. The information gathered from the RS gave an idea about the temporal and spatial changes in fresh groundwater lenses and in aquifer depth-wise changes in groundwater quality. The technical objective of the RS was to ascertain the sub-surface hydro-geological conditions in terms of groundwater quality and the nature of sub-surface materials for the selection of prospective locations for the development of fresh groundwater through the installation of tubewell. In this regard, an estimated maximum depth of about 200-225 meters has been explored by vertical electrical sounding (VES) method deploying Schlumberger electrode configuration.

In-addition to the findings of the resistivity survey, a brief account of field operations and data processing has also been given to provide the basis of the method. It includes the interpretation of VES data presented in the form of columnar sections, depicting interpreted sub-surface hydro-geological conditions (Figures B-1 to B-2). Based on the interpretation of the resistivity data, the sub-surface material has been classified into different resistivity zones for each of the scheme area as abridged in the legend. Each resistivity zone signifies typical hydro-geological conditions, which are defined under the heading of the respective zone. The sub-surface columnar sections drawn for each sounding show the interpreted picture of the sub-surface groundwater conditions in the areas investigated. Based on the results of resistivity survey, conclusions and recommendations have been framed for future planning in respect of the ground water development.

Before planning the exploitation of groundwater from the area, it is important to have diagnostic scientific information regarding the sub-surface hydro-geological conditions like:

- Lithological nature of aquifer in the areas of interest,
- Thickness and lateral extent of aquifer, and
- Estimation of the groundwater quality profiles within the depth of interest.

Electrical resistivity survey by vertical electrical sounding (VES) method is by far the most widely used technique to obtain the requisite information, which in turn help to make cost effective and technical decisions like:

- Selection of the prospective sites for the exploitation of groundwater,
- Determination of target drilling depth to avoid unnecessary exploratory drilling, and
- Identification of the nature and thickness of the aquifers in the areas of interest.

Principles of Resistivity Survey

During resistivity survey a direct current is introduced into the ground through two current electrodes A and B inserted in the ground surface. The potential electrodes M and N are inserted in the ground

between the outer current electrodes A and B where the potential difference is measured across these two potential electrodes.

By measuring the current (I) between the two current electrodes A and B and the associated potential difference (V) between the potential electrodes M and N, the resistivity is computed by the following formula:

$$\rho_a = K \times V / I \quad (1)$$

Where K is called the geometric factor of the electrode arrangement. In case of Schlumberger electrode configuration this is given by the following formula.

$$K = \pi x (AB/2) \times 2 - (MN/2) \times 2$$

Equation (1) is the general equation for calculating resistivity in electrical resistivity prospecting. If the medium is inhomogeneous and/or anisotropic then the resistivity computed from Equation (1) is called apparent resistivity and denoted by:

$$\rho_a = K \times V / I \quad (2)$$

Where:

V	=	potential difference in mill volts
I	=	current passing through ground in mill amperes
ρ_a	=	apparent resistivity in ohm-meter

The apparent soil resistivity obtained in this case represents an average value of the soils within the sphere of influence of the test setup.

Field Procedure

Signal averaging resistivity-measuring equipment (3Pa) is used for measuring current and potential values in the field. In the case of the Schlumberger array the electrodes are placed in a straight line symmetrically about the center point. The two outer electrodes A and B are used for the current, and the resulting potential difference is measured across the two inner electrodes M and N. The array is characterized by the distance of the current and potential electrodes from the center, which are referred to AB/2 and MN/2 respectively. MN/2 is always kept sufficiently small relative to AB/2. The average potential gradient measured between M and N is a close approximation to the potential gradient at the center of the array.

The ground is energized through the outer A and B electrodes under high D.C. voltage and constant current is made to flow through the ground with the help of "Power Pack" provided with the measuring equipment. The constant selected current I (in mill amperes) passing through the two current

electrodes and resulting potential difference V (in mill/micro volts) between the two potential electrodes is processed by the equipment and the R is displayed for the corresponding reading.

The distance between the two potential electrodes is smaller than the distance between either potential electrode or its adjacent current electrode. Measurements are taken and noted before repositioning the electrodes. The mid point of the electrodes is fixed at the sounding location, while the length of the configuration is gradually increased accordingly in order to measure the resistivity at given depth level. At each location, in one sounding apparent resistivity values are obtained at different specific depths.

Method of Evaluation

The resistivity field curves are obtained by plotting the apparent resistivity values against depths on a bilog graph paper. After smoothing the plotted curves all the field data is registered to computer. The interpretation of sounding is done with the help of computer and direct interpretation software. The resistivity sounding data from the area is interpreted by computer-aided techniques using INTERPEX USA, software, RESIXP. The layer models are calculated by an iterative procedure. During each iteration the model parameters are adjusted and the deviation of the corresponding curve from the measured curve is checked. The deviation is defined by the RMSE (root mean square error), which is displayed after each iteration. At the end of calculations, the model, which results in the smallest error, is plotted showing layer's true resistivity and corresponding thickness.

In practice, interpretation of resistivity sounding is invariably subjected to the principle of equivalence i.e. any resistivity sounding can be matched with several slightly deviating model curves, representing different sub-surface resistivity stratification depending upon groundwater behavior of the area. The interpreter of the data is therefore confronted with hundreds of options for a single field curve to make his selection of the most consistent model of the sub-surface conditions.

The interpreted or so called true resistivity values of the sub-surface layers and the calculated formation factor of the area has been used to estimate electrical conductivity of the groundwater for the interpreted layers. The interpreted sub-surface hydrogeological conditions are shown in the form of vertical columns at respective sounding points in Figures B-1 to B-2 depicting sub-surface hydrogeological conditions.

Interpretation of VES Data

The measured resistivities when subjected to interpretation process have yielded sub-surface electrical layers. These interpreted electrical layers need a correlation with the sub-surface geological conditions, this transformation of interpreted layers into litho logic units is essentially based on the geological information obtained from test holes, tube wells, and other data of previous investigations conducted in the area. The interpreted sub-surface conditions at each sounding location are derived in terms of resistivity and are shown in the legend below:

- Resistivity Zone I: < 10 ohm-m ECw >5000 $\mu\text{S}/\text{cm}$
- Resistivity Zone II: 10-15 ohm-m E.C w 3000-5000 $\mu\text{S}/\text{cm}$
- Resistivity Zone III :15-20 ohm-m E.Cw 2000-3000 $\mu\text{S}/\text{cm}$
- Resistivity Zone IV: 20-25 ohm-m E.Cw 1000-2000 $\mu\text{S}/\text{cm}$
- Resistivity Zone V: >25 ohm-m E.Cw <1000 $\mu\text{S}/\text{cm}$

DIAGNOSTIC ANALYSIS

For the verification of information on groundwater quality profiles in the aquifer, Resistivity Survey (RS) and Diagnostic Analysis (DA) were carried out at two sites in the command area of Kunner II distributary and Lundo minor lying at tail reaches of Rohri canal. During June 2003, services were hired from the Department of Geology, University of Sindh to conduct RS at the selected sites. Observation wells were then installed for monitoring the groundwater quality at different depths of the aquifer. Efforts are being made to develop relationship between RS and DA analysis results. To extend the skimming well technology for the safe extraction of fresh groundwater, the establishment of two field demonstration sites was planned at the farmer's fields in the selected canal commands of the Lower Indus Basin.

POTENTIAL AREAS MAPPING FOR INSTALLING SKIMMING WELLS IN THE LOWER INDUS BASIN

While comparing the results of Figure 5 with the soil physiographic conditions in the Lower Indus Basin (Figure 6), it becomes apparent that the Meander Plain represents soil type responsible for forming fresh groundwater lenses through recharge overlain by native saline groundwater layers. Figure 7, shows the areas covered by the Meander Plain in the LIB. Figure 8 presents command areas of different canals located in the Lower Indus Basin. The comparison was made using GIS of Figure 7 with Figure, and the resulting Figure 9 was developed. This figure presents the potential areas for skimming wells in different canal commands of the Lower Indus Basin.

Figure 1. Spatial distribution of waterlogged lands in the Indus Basin component of Sindh.

Figure 2. Spatial distribution of strongly salinized lands in the Indus Basin component of Sindh.

Figure 3. Spatial distribution of composite groundwater quality (0-107m depth) in the Lower Indus Basin.

Figure 4. Spatial distribution of composite groundwater quality (0-37m depth) in the Lower Indus Basin.

Figure 5. Groundwater quality areas having fresh groundwater lenses (0-37m depth) overlain by saline groundwater layers (0-107m depth) in the Lower Indus Basin.

Figure 6. Physiography of soils that exist in different canal commands of the Lower Indus Basin.

Figure 7. Spatial distribution of Meander Plain in the in the Lower Indus Basin.

Figure 8. Spatial distributions of different canal command areas in the Lower Indus Basin.

Figure 9. Potential areas for skimming wells in different canal commands of the Lower Indus Basin.

Socio-Economic Assessment of Skimming Wells in the Selected Commands of the Lower Indus Basin

Mujeeb Akhtar, Muhammad Munir, Aamir Nazir and Muhammad Nadeem Asghar

INTRODUCTION

The following two surveys were conducted in the command areas of Kunar and Lundo minors in Sindh using Participatory Rural Appraisal (PRA) techniques:

- Farmers' Perceptions, Practices and Problems (PPP) of groundwater technologies. The survey questionnaire and the collected information is given in Appendix III.
- Village-level survey of private tubewells in selected command areas. The survey questionnaire and the collected information is given in Appendix IV.

The Lundo Minor having GCA of 33000 acres with design discharge of 120 cusecs. Total length of the channel is 20 miles (100 RDs). It has 69 outlets. The Kunner II distributary is off-taking directly from the Main Rohri Canal at RD 1000 (200 miles or 322 kilometers), which is considered tail section of the Rohri Canal. The minor has about 6790 acres (2749 hectares) of Culturable command area and is being irrigated by the canal water supply of 27.88 cusecs (0.79 cumecs) of discharge. The total length of the minor is about 21 RDs (4.2 miles or 6.76 kilometers). The distributary lies in Bukerani sub division of Nasir division. In the beginning the distributary was large enough, so called Kunner Distributary but latter it was divided into two parts as Kunner I and Kunner II minors. The command area of this minor is generally fed by 16 watercourses off-taking from minor head to tail.

These surveys help to get perceptions of local communities regarding the social acceptability, economic feasibility, and technical constraints for the adoption of skimming wells in the selected canal commands of the Lower Indus Basin. The first survey was on farmer perceptions and the faced problems in current tube well pumping practice. The survey covers the head, middle and tail reaches along the Kunner II distributary and Lundo Minor. The second survey went to collect information at village level. The output of the surveys helped to find the field truth so that needed actions on farmer education and skimming-well technique disseminations.

These surveys were conducted before the installation of skimming wells pressurized irrigation system (demonstration sites). It includes two types of interview schedules: (i) Village profile in which the basic information on both the sampled distributaries was gathered on number and type of tube wells existing in the village, number of strainers, strainers' length, diameter of pipe, pump size, depth of borehole, tube well capacity, year of installation and groundwater quality. This was done through PRA with a group of key persons of the village, and (ii) another interviewing schedule was used to collect primary data regarding the perception, practices, and problems of the farmers of the selected areas.

This was undertaken by taking a sample of 72 farmers on both the distributaries. The objectives of the first survey were as follows:

- To know the existing situation in the project area, especially the perceptions, practices, and problems of tube-well owners regarding groundwater pumpage (operation/utilization pattern and cost).
- To know the awareness level of farmers regarding skimming wells pressurized irrigation system and brainstorming (in case they are not aware).
- To identify skimming well owners in general and potential farmers (for the adoption of skimming wells pressurized irrigation system) in particular.
- To make the farmers aware about the project sites (where skimming wells pressurized irrigation system is to be installed) in their area and invite them to see demonstration after its completion.

A well-designed questionnaire was developed to conduct the first survey. Key profiles, themes and variables covered in the questionnaire of first survey are presented in Table 1. Questionnaire was pre-tested and before the start of the survey two days training was arranged at Hyderabad to bring all the enumerators at the same frequency in terms of project objectives and understanding of the data collection tool.

This training helped the enumerators a lot to ensure high quality of data. All components of the study were briefed including purpose and rationale of the study, details on study areas, sampling procedures adopted and use and importance of collected data/information. The training contents covered interview methods, effective communication skills, data collection techniques, cross checking of data, units of measurement and their conversion and ethics in conducting such surveys. Each and every question in the questionnaire, and all technical and non-technical problems and issues were discussed in detail. The exercise of measuring water quality and pH was repeated and the correct uses of measuring instruments as well as tips for accurate measurements were demonstrated during the training.

BASIC CHARACTERISTICS OF THE SAMPLE FARMERS

Land Ownership

The overall land ownership of a typical farmer at the Lund and the Kunner minor is about 38 & 34 acres, respectively. The average operational holding of the farmers is about 23 & 33 acres, respectively. The average operational holding at the head, middle and tail reaches of Lundo minor is 13, 22 and 25 acres respectively, whereas at Kunner minor is 37, 38 and 27 acres respectively.

Table 2. Key profiles, themes and variables covered in the questionnaire of first survey.

Profile	Theme	Data Detail	Purpose/Output
Land Profile	Existing situation	Land ownership, farm area, culturable waste area, reasons of culturable waste area, fallow land, salt affected area, area under orchard.	To evaluate farm area situation
Irrigation Profile	Existing situation	Source of irrigation, canal irrigation turn time, canal irrigated area, share of tube well water in total irrigation, water table depth, groundwater quality.	To estimate dependence on groundwater
Type and features of tube wells	Farmers' Practice	Type of tube well, type of ownership, source of power, year of installation, specified life, capacity, depth of bore, depth of sump, diameter of sump, diameter of suction pipe, size of pump, mode of transmission, discharge, number of strainers, type of strainer, length of strainer, diameter of strainer.	To evaluate characteristics of tube wells used in the project area
Cost of tube well	Farmers' Practice	Installation cost, re-boring cost, seasonal operational cost, seasonal maintenance and repair cost	To calculate costs for comparative analysis
Utilization of tube well	Farmers' Practice	Daily operation hours during slack and peak periods, average fuel consumption from different types of tube wells, average time spent to irrigate one acre from different irrigation sources, seasonal selling of tube well water and average rate	To estimate operation hours and pattern of different tube wells and its impact on aquifer
Crop information	Farmers' Practice	Area under crops, crop-wise frequency of irrigation from different irrigation sources, yield per acre	To estimate cropping pattern, cropping intensity, quantity of water applied
General Information	Farmers' Perception	Reason to install tube well, reason of selecting type of tube well, opinion and experience of different types of well, decision on different tube well types, depths, diameter, number of strainers, size of pump, and prime mover.	To know who is making the decisions and how?
General Information	Farmers' Practice	Farmers' practices to manage water quality, salinity/sodicity, and its affect on land and crop productivity.	To know the practice for recommending a better policy
General Information	Farmers' Problem	Most pinching problem related to groundwater pumpage and its management, availability of local experts, canal water supply situation, etc.	To recommend solution in the form of skimming well
General Information	Awareness	Awareness about marginal and brackish groundwater layer, sprinkler and trickle irrigation systems, willingness to adapt.	To know farmers' awareness level and willingness for designing the second survey of constraints in socio-economic adaptability.

Culturable Waste Land

About 40 % farmers have an average culturable wasteland of about 7 acres. Most of the farmer's land was wasted during 1990s. The farmers reported the following main reasons for this culturable wasteland at Lundo and Kunner Minor: (i) scarcity of water, (ii) salinity/sodicity, (iii) financial problem, and (iv) unlevelled land.

The maximum culturable wasteland was found at the tail reaches of the Lundo and the Kunner Minor. Figure 1 and 2 show the average percentage of farmers having culturable wasteland at the head, middle and tail reaches of Lundo and Kunner Minor.

Figure1. The average percentage of farmers having culturable wasteland at Lundo and Kunner Minor.

Figure 2. The percentage of farmers having culturable wasteland at head middle and tail location at Lundo and Kunner Minor.

Fellow Land

High percentage of average fellow land was observed at Lundo and Kunner Minor. On an overall basis, more than 80% farmers have fellow land in both Rabi and kharif season due to shortage of

water for irrigation purposes. The average fallow land in Kharif and Rabi season is 12 and 17 acres respectively. Figure 3 and 4 show in detail the average fallow land in Rabi and Kharif season at Head, Middle and the Tail reaches of the Lundo and the Kunner Minor.

Figure 3. The percentage of farmer having fallow land and average area in Rabi and Kharif season at Lundo and Kunner Minor.

Figure 4. The average fallow land at Head, Middle and Tail in Rabi and Kharif season at Lundo and Kunner Minor.

Salt Affected Area

Salinity /sodicity is the major problem in the command areas of Lundo and Kunner minor. This salt affected area is found in patches. About 50% farmers reported that they have salt affected land in patches, with an average land of about 6 acres per holding. The farmers at the Tail end were found the most sufferers. Mostly the salt affected land was at the tail reaches of Lundo and Kunner minor. Figure 5 and 6 show in depth the average percentage of farmers having salt affected area at the head, middle and tail reaches of Lundo and Kunner Minor.

Figure 5. The percentage of farmers having salt affected area and average area at Lundo and Kunner Minor.

Figure 6. The average salt-affected area at Head, Middle and Tail at Lundo and Kunner Minor.

Area Under Orchard

The mango orchards are the most common in the command area of Lundo and Kunner minor. More than 40% farmers have an average orchard area of about 5 acres. The average percentage of farmers having orchard area at head, middle and tail reaches of Lundo minor is 17, 29 and 23 percent, whereas, on Kunner minor, the average percentage is 26, 32 and 42 percent respectively.

IRRIGATION PROFILE OF THE STUDY AREA

Main Sources of Irrigation at the Farm

Mostly the farmers irrigated their lands with canal water. The average turn time at Lundo and Kunner minor is about 17 minutes. However, almost all the farmers used the groundwater as the supplemental source of irrigation with canal water. The average area irrigated with the turn time is ranged from 7-13 acres depending upon the location of land and type of well and its discharge.

The percentage share of groundwater in total irrigation varies from 20 to 100%. Only 12% farmers are observed completely depend on groundwater for irrigation purposes. The use of canal water is maximum at the head reach and the minimum at the tail reach of the Lundo and Kunner minor. Figure 7 shows in detail the percentage share of groundwater in total irrigation at head, middle and tail reached of Lundo and Kunner minor.

Figure 7. The share of groundwater in total irrigation at the head, middle and tail locations of watercourses at Lundo and Kunner Minor.

Water Table Depth and Water Quality

The average water table depth varies from 16 to 18 ft at Lundo minor and 30 to 36 ft at the Kunner minor. PH value of water samples ranged from 7.4 to 8.4 with an average value is 7.8 at Lundo and Kunner minor.

The groundwater is mostly saline at Lundo and Kunner minor command area. Only 18 % water samples at Lundo and 87% at Kunner minor were found fit for irrigation purposes. Figure 8 shows in detail the water quality (measured vs. farmer's perception) at Lundo and Kunner minor.

Groundwater Development at Lundo and Kunner Minor

There are 153 wells in total at Lundo and 223 wells at Kunner minor. The skimming wells are 33% at Lundo and 17% at Kunner minor. Figure 9 presents the detail of skimming wells and their number of strainers.

Figure 8. The water quality measured vs. farmer's perception at Lundo and Kunner Minor.

Figure 9. The wells, tubewells and skimming wells at Lundo and Kunner Minor.

TECHNICAL DETAILS REGARDING DIFFERENT TYPES OF WELL AT THE SELECTED MINORS

Status of Type of Ownership

More than 55% farmers have single ownership and rest 45 % has joint ownership of the wells at Lundo and Kunner minor. The joint ownership trend is more at the head reach of Lundo and Kunner minor. Figure 10 shows in detail the ownership status at head, middle and tail reaches at Lundo and Kunner minor.

Figure 10. The ownership status of wells at head, middle and tail location of the Lundo and Kunner Minor.

Sources of Power & Capacity (HP)

The main source of power for well operation at Lundo and Kunner minor is diesel with an average capacity of 16-25 hp. Mostly the diesel operated wells are driven by peter engine. Only 15% tractor operated wells were found at Kunner minor, and the electric operated wells are few in number (5%) and have an average capacity ranged from 10 to 25 HP (Figure 11).

Figure 11. The wells operated by different sources of power at Lundo and Kunner Minor.

Year of Installation & Specified Life

Mostly the wells were installed during 1990s and 2000 onward at both Lundo and Kunner minor. This data shows that the groundwater demand was increased highly during 1990s and 2000 onward. The farmers reported that the average specified life of a "tubewell" is 6 to 15 years with an average of 12 years. Whereas the skimming well average specified life is found 4-10 years. This shows that the skimming wells are sustainable well type in this area.

Depth of bore and Size of Pump

The average bore depth of the tubewell is 126-160 ft with pump size most commonly is 5 inches delivery size and 6 inches suction size at Lundo and Kunner minor. Whereas, the bore depth for skimming wells ranged from 60 to 90 ft with the same pump size as for tubewell. Almost all wells at Lundo and Kunner minor were observed driven by belt. Almost all the tubewells have the sump. The average depth of the sump is ranged from 11 to 24 ft and diameter is of 10ft at Lundo and Kunner Minor.

Type, Number, Length & Diameter of Strainers

There are mostly three types of strainers were found at Lundo and Kunner minor, i.e., plastic, steel and iron strainers. Tubewell has only one strainer. The skimming well has the range of strainers 2 to 14. Commonly 8 or 10 strainers are used for skimming well installation. Overall length of strainer is 60 ft with an average diameter of 5 inches. Plastic Strainers are commonly of 18 to 20 ft in length and Steel/iron Strainers are of 80 to 100ft both with an average 2-6 inches diameter were using at Lundo and Kunner Minor. Tubewells commonly have steel strainers but the Skimming Wells have both Plastics (77.8 % wells) and Steel Strainers (22.2%).

Installation Cost and Cost of Re-bore

The installation cost depends upon a lot of factors i.e., bore depth, type of strainers, length of strainers etc. The overall cost of a well is Rs. 66238 to 101964. The cost of the tubewell is ranged in between Rs. 77833 to 110435 depending upon the type of sources and other above-mentioned factors, whereas the cost of installation of skimming well ranged from Rs. 50778 to 63000 at Lundo and Kunner minor. This indicates that the skimming wells are the least cost solution for irrigation purposes at Lundo and Kunner Minor. It is worth mentioning that about 52% tubewells were re-bore at the average cost of Rs. 39167.

MAIN REASONS TO SELECT AND INSTALL THE WELLS

Almost all the farmers reported that the main reason to install the wells is "Scarcity of water/canal water" considering groundwater as the most reliable source of irrigation. Selection of well was the major issue in this area because the groundwater quality is saline. Commonly, the tubewell and

skimming wells are used in this area for the extraction of groundwater. Skimming well technology was used for extracting fresh groundwater. People have different point of view about these well types in this area. More than 45% farmers indicated that they select the particular type of well (i.e., tubewell/skimming well) because it is the common practice in the respective village or his fellow farmer has the same type of well.

The farmers who installed tubewell because of the reasons that it gives more discharge, common in market and spare parts & mechanics are easily available and dislike the skimming well due to the fact that if any strainer of the Skimming Well is choked, it is difficult to trace it. Whereas, on the other hand, the farmers who are in favor of the installation of Skimming well, they quote the reason that it works better at very shallow water table depth and provides good quality of groundwater as compare to tubewell in the area. Furthermore, its installation and repair cost is low as compare to tubewell.

FARMER'S PRACTICES REGARDING GROUNDWATER EXTRACTION TECHNOLOGIES

Practices of Well Design Decisions

About 60% respondents reported that they decide about the type of well, depth & diameter of the well, number of strainers and horizontal distance between strainers with their "Own Will". Rest 35% respondents indicated that they decide about the type of well with the "Advice of Mechanics". And only 5% used their own will and also discuss with local mechanic in order to well design decisions.

Irrigation Requirements and Wells

About 70% respondents reported that their present wells fulfill their irrigation requirements with out any problem. But 30% respondents reported that they are facing problem while using their well for irrigation requirements. They reported the problems rank-wise are of the following:

- The farmer has fragmented land; so one well did not fulfill their irrigation requirements.
- The farmer has his land at the tail end of the watercourse/minor.
- The groundwater quality is saline.
- Fuel is costly.
- The soil type is sandy and it can not satisfied the need of the area

Utilization Factor of Wells

The utilization factor is the total pumping hours utilized by a well during the year. Utilization factor depend upon a lot of factors i.e., rainfall, canal water supplies, cropping pattern, area irrigated, water quality etc. The overall utilization factor of a well at Lundo and Kunner minor varies from 3 to 19%. The utilization factor of tubewell was estimated 3 to 19%, whereas for skimming well 2.2 to 13.4%

was estimated. Table 2 shows the detail of slack & peak utilization factors during Rabi and Kharif season.

Table 2. The detail of slack & peak utilization factors during Rabi and Kharif season.

Lundo Minor

Type of Well	Average Daily Hours			
	Rabi		Kharif	
	Slack	Peak	Slack	Peak
Tubewell	9.8	10.3	12.0	12.2
Skimming Well	7.8	8.7	9.8	10.7
Overall	9.3	9.6	11.1	11.5

Type of Well	Average Operating Days			
	Rabi		Kharif	
	Slack	Peak	Slack	Peak
Tubewell	16	31	19	36
Skimming Well	14	23	17	26
Overall	15	27	18	32

Type of Well	Average Annual Utilization Factor (%)			
	Rabi		Kharif	
	Slack	Peak	Slack	Peak
Tubewell	3.6	7.3	5.2	10.0
Skimming Well	2.5	4.6	3.8	6.3
Overall	3.2	5.9	4.5	8.4

Kunner Minor

Type of Well	Average Daily Hours			
	Rabi		Kharif	
	Slack	Peak	Slack	Peak
Tubewell	10.3	12.6	13.4	16.2
Skimming Well	12.0	13.6	14.6	16.4
Overall	10.5	12.8	13.6	16.2

Type of Well	Average Operating Days			
	Rabi		Kharif	
	Slack	Peak	Slack	Peak
Tubewell	13	19	44	54
Skimming Well	8	10	24	36
Overall	12	18	41	51

Type of Well	Average Annual Utilization Factor (%)			
	Rabi		Kharif	
	Slack	Peak	Slack	Peak
Tubewell	3.1	5.5	13.4	19.9
Skimming Well	2.2	3.1	8.0	13.4
Overall	2.9	5.3	12.7	18.8

Average Fuel Consumption of a Well

The overall average fuel consumption of diesel operated wells ranged from 2.2 to 2.9 liter per hour, whereas, overall average electricity consumption of electric operated wells ranged from 7 to 16 kwh.

The average time spent to irrigate one acre by a "well only water" is 3 to 5 hours and the average time spent to irrigate one acre by a "Canal + well only water" about 1 to 2 hours.

Average O & M Cost of the Well

The average O& M cost of the diesel well varies from Rs. 15000 to 48000 depending on the pumping hours (utilization factor) of the well. This cost includes the fuel cost, Mobil change cost and repair cost. Table 3 provides the detail of the diesel and electric wells in Rabi and Kharif season at Lundo and Kunner Minors.

Table 3. The detail of the diesel and electric wells in Rabi and Kharif season at Lundo and Kunner Minors.

Lundo Minor

O & M Items	Rabi		Kharif	
	Diesel Operated Wells	Electric Operated Wells	Diesel Operated Wells	Electric Operated Wells
Diesel Bill (Rs.)	12189	N.A.	19295	N.A.
Electric Bill (Rs.)	N.A.	4256	N.A.	13589
Mobil Oil Change Duration (hours)	74	N.A.	75	N.A.
Cost of Oil (Rs.)	345	N.A.	354	N.A.
Repair Cost (Rs.)	1463	985	3283	1895

Kunner Minor

O & M items	Rabi		Kharif	
	Diesel Operated Wells	Electric Operated Wells	Diesel Operated Wells	Electric Operated Wells
Diesel Bill (Rs.)	14183	N.A.	45074	N.A.
Electric Bill (Rs.)	N.A.	8400	N.A.	18900
Mobil Oil Change Duration (hours)	90	N.A.	90	N.A.
Cost of Oil (Rs.)	474	N.A.	470	N.A.
Repair Cost (Rs.)	1533	910	2267	2110

Water Marketing

Only 4% respondents reported that they sale groundwater. The average hours of sale were 12 –15 and the rate was @ Rs.85-100 per hour in Rabi season whereas in Kharif season, the average sale was about 16-110 hours @ Rs. 95-100 per hour.

Cropping pattern and Irrigation Requirements

The main cropping pattern is wheat-fodder/wheat-cotton at Lundo and Kunner Minor. Mostly the canal and well water source of irrigation was used at the command area of Lundo and Kunner Minor. Table 4 provides the detail of the cropping pattern and the irrigation requirements of the crops.

Table 4. The detail of the cropping pattern and the irrigation requirements of the crops.

Lundo Minor

Crop	Average Area (acres)	Average Yield Per Acre (monds)	No. of Irrigations			
			Total	Canal Only	Well Only	Canal + Well
Rabi Crops						
Wheat	14.8	25.1	5	1	3	1
Fodder	2.1	280.6	5	1	3	1
Vegetables	1.5	38.5	13	3	18	0
Oil seed	7.9	15.9	4	1	2	1
Kharif Crops						
Wheat	17.9	16.6	9	3	4	2
Fodder	1.9	260.5	8	4	2	2
Vegetables	1.8	28.6	14	6	4	4
Oil seed	1.0	15.5	6	3	1	2
Annual Crops						
Sugarcane	4.0	583	12	3	5	4
Orchards	12.9	Rs. 7000/acre	10	2	5	3

Kunner Minor

Crop	Average Area (Acres)	Average Yield Per Acre (monds)	No. of Irrigations			
			Total	Canal Only	Well Only	Canal + Well
Rabi Crops						
Wheat	10.9	25.5	7	1	4	2
Fodder	4.2	303	8	2	3	3
Vegetables	4.5	51.8	6	1	4	1
Oil seed	10.9	25.5	7	1	4	2
Kharif Crops						
Wheat	6.6	14.2	8	2	4	2
Fodder	3.6	264	9	1	5	3
Vegetables	5.6	27.8	8	3	4	1
Oil seed	6.6	14.2	8	2	4	2
Annual Crops						
Sugarcane	10.8	634	18	4	5	9
Orchards	11.3	Rs. 7800/acre	11	3	5	3

Water Quality & Salinity Problem at the Farm and Its Management

Deteriorating groundwater quality and the salinity problems are the main issues at Lundo and Kunner Minor command area. When farmers were asked, how the poor water quality and salinity is affecting their land and crop productivity; they indicated that the crop yield drastically reduced and the land becomes harder due to poor water quality. Almost all the farmers have the idea how to recognize the

salinity/sodicity problem. They recognize the water quality at their farm by the taste of water and salinity by observing white color appears on the surface.

As regard for the management of this poor water quality and salinity problem, about 25% farmers indicated that they did not know how to manage this problem. But 60% farmers reported that they managed the water quality and salinity problem by applying the conjunctive use of canal water and groundwater. They also cultivated the salinity/sodicity resistant crops in order to combat the salinity problem.

FARMER'S PROBLEMS REGARDING GROUNDWATER EXTRACTING TECHNOLOGIES

Main Pinching Problems and its Management Strategies

The farmers indicated different pinching problems regarding the wells operation. Some farmers who are the owners of the electric operated wells reported that that they did not face any pinching problem. The farmers who have wells operated by diesel source of power mentioned the following pinching problems:

- Maintenance of engine
- The "starting" trouble of the diesel engine
- The price of fuel (diesel)
- The maintenance of foot valve and the pump

As regard to tackle these pinching problems, about 60% farmers reported that they consulted mechanics and by utilizing some personal collective efforts they handle the above-mentioned pinching problems to some extent. They have suitable local expert facility in order to solve their problems. But the rest 40% farmers indicated that they did not know how to manage these particular type-pinching problems. Furthermore, these farmers have not sufficient funds to call local expert which resulted the failure of well.

Expectation of Farmer's from Government Agencies

The farmers showed a high expectation from government agencies. Some of these expectations of the farmers are described below:

- Mostly the farmers are worry about the problem of rising prices of diesel fuel. Some farmers suggested that govt. provide diesel on subsidized rates and most farmers showed high interest in "Electric operated wells". Electric operated wells are cheaper in running & repair cost as compare to diesel operated well. Farmers showed willingness in the installation of electric operated wells if the government provides free electrical connections and subsidy on the rates of electricity.

- Some farmers also demanded that the rates of Usher, taxes and Abiana (water rates) should be reduced subject to canal water supplies/availability.
- Farmers suggested that the prices of fertilizer, seed and pesticide should be subsidized.
- Farmers also suggested that in order to increase the irrigation water supplies, the government should install a tubewell (of about 3 to 5 cusecs) at the head of the watercourse outlet.
- The government should start to provide fuel (diesel) to farmers on credit.

GENERAL CONCLUSIONS AND SUGGESTIONS

Farmer's Perceptions Regarding Canal Water Supplies Management

A few farmers (20%) reported that they are satisfied with canal water supplies and rest 80% farmers are not satisfied with canal water supplies. The farmers who are not satisfied with canal water supplies gives the following comments of dissatisfaction;

- The farmers at the head reach of the watercourse takes the shares of the middle and tail end farmers
- The canal water supplies is irregular or low
- The canal management by PID staff is unsatisfactory
- The minor/distributary is silted up that reduced the canal water supplies.
- There is water theft at the head or middle reaches of the watercourse/minor.

The farmers suggested the following suggestions in order to improve the canal water supplies;

- To provide the designed or allocated discharge of canal water to the respective outlets and reaches of the watercourse
- Through better canal rotation management
- Water theft should be controlled
- By silt clearance program.

Awareness About Pressurized Irrigation System and Willingness to Adopt

Awareness about Fresh Groundwater Layers

Only 25% farmers have the idea about the fresh groundwater layers underlain by marginal to brackish groundwater layer. The rest 75% did not know about the fresh groundwater layers.

Know-how About Pressurized Irrigation System

About 85% farmers reported that they have no any technical or simple know-how about pressurized irrigation system and rest 15% farmers only know a little bit about the pressurized irrigation system.

Willingness to Adopt the Pressurized Irrigation System

About 65% farmers reported that they have willingness to adopt pressurized irrigation system depending upon its economical viability. Some 25% farmers reported that after seeing this system in operation, the decision about willingness to adopt this system could be made. Only 10% farmers showed completely unwillingness to adopt this irrigation system due to unable to understand its technical design and farming operations mechanism.

It is probably worthwhile mentioning here that timely policy support from the government is very much needed in new technique extension. In this light, IWMI Pakistan has spent efforts to widen involvement of SIDA and other government agencies in the project. The adoption of skimming well technology will not only solve environmental constraints, but also provide cost-affected on-farm water control system, on demand availability of good quality irrigation water and lowering of depth to water table within permissible level.

INTERVIEW WITH THE FARMERS AND FIELD PHOTOGRAPHS

Water Quality Survey of Tubewells in Hyderabad District

Zahid Aziz, Muhammad Nadeem Asghar and Muhammad Munir

INTRODUCTION

In Pakistan, annual precipitation and canal water availability at farm level is not enough to support the needs of extensive cropping system. To overcome this deficiency of irrigation water, farmers have to use groundwater extracted using tubewells. However, the fitness of groundwater for irrigation purposes should not be taken as granted. Therefore, care should be taken while applying groundwater for irrigational purposes; otherwise many socio-economic and environmental issues would arise. Recently, Fauji Fertilizer Company Limited initiated the Mobile Farm Extension Services of Agricultural Laboratory for advisory services to farmers regarding the suitability of their pumped groundwater for irrigational purposes. This report presented the results of four Hundred and seventy-six pumped water samples obtained from Hyderabad district. The irrigation water quality criteria of the Water and Power Development Authority (WAPDA) were used for guidance purposes (Table 1).

Table 1. Irrigation suitability criteria of WAPDA.

Water Quality	Total Dissolved Salts (ppm)	SAR (m mole/l) ^{1/2}	ESC (me/l)
Fit	< 1000	< 10	< 2.5
Marginal	1000 - 2000	10 - 18	2.5 - 5.0
Hazardous	> 2000	> 18	> 5.0

The samples were analyzed for providing the guidance to farmers about their tubewells water suitability for irrigation purposes. The tehsil-wise results are presented in Table 2.

Table 2. Tehsil-wise pumped water suitability for irrigation purposes.

Tehsil	Fit (%)	Marginal (%)	Hazardous (%)
Hyderabad	53	24	23
Tando Allah Yar	48	34	18
Tando Muhammad Khan	86	14	0
Matiari	25	20	55
Hala	50	21	29

BASIC INFORMATION OF THE SURVEY

The depths of these samples ranged: (i) from 6 to 65m in Tehsil Hyderabad (average depth was 20m), (ii) from 6 to 75m in Tehsil Tando Allah Yar (average depth was 30m), (iii) from 6 to 30m in Tehsil Tando Muhammad Khan (average depth was 20m), (iv) from 15 to 55m in Tehsil Matiari

(average depth was 25m) and (v) from 18 to 50m in Tehsil Hala (average depth was 35m). Table 3 presented the detail of depths of sampled tubewells from Hyderabad district.

The tehsil-wise detail of the samples collected is: (i) 256 samples were taken from 107 locations of Tehsil Hyderabad, (ii) 120 samples from 41 locations of Tehsil Tando Allah Yar, (iii) 66 samples from 16 locations of Tehsil Tando Muhammad Khan, (iv) 20 samples from 9 locations of Tehsil Matiari and (v) 14 samples from 4 locations of Tehsil Hala.

Table 3. Depth of sampled tubewells from Hyderabad district.

Tehsil	Min.	Max.	Avg.	Standard Deviation (SD)	Coefficient of Variation (CV)
(tubewells depths in meters)					
Hyderabad	6	65	20	8	18
Tando Allah Yar	6	75	30	14	17
Tando Muhammad Khan	6	30	20	8	19
Matiari	15	55	25	9	20
Hala	18	50	35	10	22

QUALITY OF PUMPED WATER FIT FOR IRRIGATION PURPOSES

Table 4 presented the detail of pumped water quality of sampled tubewells from Hyderabad district. Out of 476 tubewells water samples 262 (55%) were found fit for irrigation purposes.

In Tehsil Hyderabad, out of 256 pumped water samples 136 (53%) were fit for irrigation purposes, having average TDS, SAR and RSC values equal to 680 ppm, 229 (m mole/l)^{1/2}, and 0.45 me/1, respectively. Thirty-eight samples were free of RSC.

In Tehsil Tando Allah Yar, out of 120 pumped water samples 57 (47%) were fit for irrigation purposes, having average TDS, SAR and RSC values equal to 663 ppm, 2.70 (m mole/l)^{1/2}, and 0.94 me/1, respectively. Twenty-nine samples were free of RSC.

In Tehsil Tando Muhammad Khan, out of 66 pumped water samples 57 (86%) were fit for irrigation purposes, having average TDS, SAR and RSC values equal to 610 ppm, 2.23 (m mole/l)^{1/2}, and 0.94 me/1, respectively. Forty samples were free of RSC.

In Tehsil Matiari, out of 20 pumped water samples 5 (25%) were fit for irrigation purposes, having average TDS, SAR and RSC values equal to 403 ppm, 1.30 (m mole/l)^{1/2}, and 0.65 me/1, respectively. One sample was free of RSC.

In Tehsil Hala, out of 14 pumped water samples 7 (50%) were fit for irrigation purposes, having average TDS, SAR and RSC values equal to 565 ppm, 2.21 (m mole/l)^{1/2}, and 0.65 me/1, respectively. Three samples were free of RSC.

Table 4. Usable tubewells water samples of District Hyderabad.

Tehsil		TDS	SAR	RSC
Hyderabad	Number of samples	136	136	98
	Average	679.72	2.29	0.45
	SD	199.23	1.02	1.08
	CV	70.69	55.47	139.41
Tando Allah Yar	Number of samples	57	57	28
	Average	663.00	2.70	0.94
	SD	219.00		0.71
	CV	66.97		24.54
Tando Muhammad Khan	Number of samples	57	57	17
	Average	610.58	2.23	0.94
	SD	143.27	1.04	1.09
	CV	76.54	53.15	16.14
Matlari	Number of samples	5	5	4
	Average	403.20	1.30	0.65
	SD	163.36	0.48	0.39
	CV	59.46	62.71	40.42
Hala	Number of samples	7	7	4
	Average	565.03	2.21	0.65
	SD	198.42	1.31	0.83
	CV	64.88	40.69	28.41

QUALITY OF PUMPED WATER MARGINAL FOR IRRIGATION PURPOSES

Table 5 presented the detail of marginal tubewells from Hyderabad district. Out of 476 tubewells water samples 119 (25%) were found marginal for irrigation purposes.

In Tehsil Hyderabad, out of 256 pumped water samples 62 (24%) were marginal for irrigation purposes. Out of these 62 samples, 46 samples were marginal due to TDS, 6 due to RSC, 1 due to TDS+SAR, 3 due to TDS + RSC and 6 due to TDS+SAR+RSC.

In Tehsil Tando Allah Yar, out of 120 pumped water samples 41 (34%) were marginal for irrigation purposes. Out of these 41 samples, 31 samples were marginal due to TDS, 1 due to SAR, 3 due to RSC, 2 due to TDS+SAR and 4 due to TDS+RSC.

In Tehsil Muhammad Khan, out of 66 pumped water samples 9 (14%) were marginal for irrigation purposes. Out of these 9 samples, 4 samples were marginal due to TDS, 1 due to TDS+SAR and 4 due to TDS+RSC.

In Tehsil Matiari, out of 20 pumped water samples 4 (20%) were marginal for irrigation purposes. Out of these 4 samples, 1 sample was marginal due to TDS, 1 due to RSC and 2 due to SAR+RSC.

In Tehsil Hala, out of 14 pumped water samples 3 (21%) were marginal for irrigation purposes. All these three samples were marginally fit due to TDS.

Table 5. Quality of marginal tubewells water of District Hyderabad (Tehsil-wise).

Parameters		Hyderabad	Tando Allah Yar	Tando Muhammad Khan	Matiari	Hala
TDS	n	46	31	4	1	3
	%	74.19	75.60	44.44	25	100
	SD	245.35	265.41	281.04		102.67
	CV	81.84	81.18	81.13		94.17
SAR	n	0	1	0	0	0
	%		2.43			
	SD					
	CV					
RSC	n	6	3	4	1	0
	%	9.67	7.31	44.4	25	
	SD	0.92	2.61	0.67		
	CV	76.02	27.62	80.71		
TDS+SAR	n	1	2	1	0	0
	%	1.6	4.87	11.11		
	SD		444	0.0		
	CV		67	100		
EC+RSC	n	3	4	0	0	0
	%	4.83	9.75			
	SD	102.47	0.42	105.50	0.70	
	CV	80.97	85.80	91.00	81.0	
SAR+RSC	N	0	0	0	2	0
	%				50	
	SD				1.7	1.27
	CV				86.84	68.18
TDS+SAR+RSC	n	6	0	0	0	0
	%	9.67				
	SD	329.33	0.2			
	CV	80.38	95.7			
Total		62	41	9	4	3

QUALITY OF PUMPED WATER HAZARDOUS FOR IRRIGATION PURPOSES

Table 6 presented the detail of hazardous sampled tubewells from Hyderabad district. Out of 476 water samples 95 (20%) revealed water quality hazardous for irrigation purposes. In Tehsil

Hyderabad, out of 256 samples, 58 (23%) water samples were found hazardous for irrigation purposes. Out of these 58 samples, 42 were hazardous due to TDS, 13 due to RSC, 2 due to SAR+RSC, and 1 due to TDS+SAR+RSC. In Tehsil Tando Allah Yar, out of total 120 water samples, 22 (18) samples showed hazardous quality for irrigation purposes. Out of these 22 samples, 13 samples were hazardous due to TDS, 5 due to RSC and 4 due to TDS+RSC. In Tehsil Tando Muhammad Khan, out of total 66 water samples, none was found hazardous for irrigation purposes. In Tehsil Matiari, from total 20 water samples, 11 (55%) samples showed hazardous quality for irrigation purposes. Out of these 11 samples, 8 samples were hazardous due to RSC and 3 due to SAR+RSC. In Tehsil Hala, from total 14 water samples, 4 (28%) samples showed hazardous quality for irrigation purposes. Out of these 4 samples, 2 samples were hazardous due to TDS and 2 due to TDS+SAR.

Table 6. Quality of unfit tubewells water samples of District Hyderabad (Tehsil-wise).

Parameters		Hyderabad	Tando Allah Yar	Tando Muhammad Khan	Matiari	Hala
EC	n	42	13	0	0	2
	%	72.41	59.09			50.00
	SD	876.32	821.30			2122.45
	CV	69.30	68.72			43.26
SAR	n	0	0	0	0	0
	%					
	SD					
	CV					
RSC	n	13	5	0	8	0
	%	22.41	22.72		72.72	
	SD	1.96	3.80		1.12	
	CV	76.22	48.77		82.97	
EC+SAR	n	0	0	0	0	2
	%					50
	SD					6842.53
	CV					0.36
						7.85
EC+RSC	n	0	4	0	0	0
	%		18.18			
	SD		1915.78	1.61		
	CV		46.45	83.36		
SAR+RSC	n	2	0	0	3	0
	%	3.44			27.27	
	SD	0.92	1.70		0.40	1.68
	CV	95.46	81.95		97.94	84.42
EC+SAR+RSC	n	1	0	0	0	0
	%	1.72				
	SD					
	CV					
Total		58	22	0	11	4

SUMMARY

- Water quality parameters responsible for making the water samples marginal were: (i) TDS for Tehsil Hyderabad, Tando Allah Yar and Hala, (ii) TDS and RSC for Tehsil Tando Muhammad Khan and (iii) SAR+RSC for Tehsil Matiari. However, for most of the marginal samples, SAR was not so high to create any considerable problem.
- In whole Hyderabad district, TDS and RSC are causing most of the tubewells water to be Hazardous for irrigation purposes. All other parameter such as, SAR, EC+SAR, EC+RSC, SAR+RSC and EC+SAR+RSC have negligible role to make the pumped water hazardous for irrigation purposes.
- Most of the tubewells are having shallow depths. Farmers are aware off the thin fresh groundwater lenses overlying the saline groundwater layers a prerequisite for installing skimming wells. The quality of pumped water being marginal and hazardous for irrigation purposes showed that the saline groundwater upconing occurred in these tubewells –this upconing could be avoided using skimming wells.

Capacity Building

The involvement of IIDE in this project is considered for capacity building of:

- Post graduated students (Mr. Muhammad Munir Ahmed and Mr. Mashooque Ahmed Talpur) for conducting Participatory Rural Appraisal (PRA) to investigate farmers' reaction and acceptance of skimming wells, and for establishing field demonstrations sites of skimming wells to supply water through drip irrigation system for newly planted *bair* orchards; and
- Postgraduate students for using Geographic Information System (GIS) to delineate areas in Sindh where skimming well technology can successfully be applied. The nominees are:
 - Ms. Nosheen Khushk, B-79 Naseem Nagar, Qasimabad, Hyderabad. Ph: 0221-651883. Email: only1-k@hotmail.com
 - Mr. Ali Raza Lashari, Banglo No. 16, Gulestan Dastageer Colony, Near Saima Plaza, Hala Naka Road, Hyderabad. Ph: 0221-640175 and 622311
 - Mr. Ali Nawaz Memon, Room No. 217, Dr. Abdul Qadir Hostel, MUET, Jamshoro. Ph: 0221-771335. Email: arma-sahil33@yahoo.com
 - Mr. Muhammad Munir Ahmed, and
 - Mr. Mashooque Ahmed Talpur.

The involvement of SIDA in this project is considered for capacity building of:

- Farmers, including women farmers, on using skimming wells to supply water through drip irrigation system for newly planted *bair* orchards. The established network of FOs under SIDA could be mobilized for organizing field workshops. IWMI have already installed two demonstration sites in the command of Kunner II distributary and Lundo Minor on Rohri Canal; and
- Research & Development (R&D) wing of SIDA for using Geographic Information System (GIS) to delineate areas in Sindh where skimming well technology can successfully be applied. The nominees are:
 - Dr. Mumtaz Ahmed Sohag, GM (R&D)
 - Mr. Irshad Ahmed Bahio (Director/TL), EMU
 - Mr. Ali Asghar Mahessar (Water Resources), EMU
 - Mr. Noman Ali (Computer Administrator), EMU
 - Ms. Farzana Memon (GIS), EMU
 - Ms. Romiza Kharal (Environmental Research Assistant II), R&D

The involvement of WRRI-NARC in this project is considered for capacity building of:

- Resistivity Survey to ascertain the sub-surface hydro-geological conditions in terms of groundwater quality and the nature of sub-surface materials for the selection of prospective locations for the development of fresh groundwater through the installation of tubewells, and
- Training for using Geographic Information System (GIS) to delineate areas in Sindh where skimming well technology can successfully be applied. The nominees is:
 - Mr. Ghulam Ali, Deputy Director, PARC, Islamabad.

All the collaborators are actively involved in dissemination as well as field activities. Their participation is considered on the basis of actual costs that will occur in undertaking the project activities. Arrangements have also been made to hold a training workshop on GIS analysis and mapping for capacity building of project collaborators -SIDA, WRRI-NARC and IIDE-Mehran University. The expected participants are 15 (7 from SIDA, 2 from WRRI-NARC and 6 from IIDE-Mehran University).

Dissemination

ESTABLISHMENT OF SITES

Two field trips were made to Sindh for the skimming-well pilot sites. Based on indoor GIS/RS analysis and field survey, two sites were chosen: Shahdad Pur in the command of Lundo Minor and Sheikh Barkeo in the command of Kunner II distributary. Table 1 presents the salient features of Kunner II Distributary and Lundo Minor. These two sites well fit the hydro-geological conditions for the use of skimming wells, and the farmers' awareness of groundwater management is relatively good from their well pumping practice. In the processes, the Sindh Irrigation and Drainage Authority (SIDA), Water Resources Research Institute of NARC (WRRRI-NARC), and Institute of Irrigation and Drainage Engineering (IIDE) of Mehran University were involved and very supportive. The Sindh Agriculture and Forest Workers Coordinating Organization (SAFWCO), a local NGO, also participated to the site selection based on their local experience.

Table 1. Salient Features of Kunner II Distributary and Lundo Minor.

Salient Features/Minor	Kunner II Distributary	Lundo Minor
Main Canal	Rohri Canal	Ali Bahar Branch
Off-shooting RD from Main Canal	1000	22.5
Location at Main Canal	Tail	Tail
Irrigation Division	Nasir	Hala division
Irrigation Sub-division	Bukerani	Shahdadpur
Nature of Water Supply	Perennial	Perrenial
GCA (hectares)		13360
CCA (hectares)	2749	
Length (kilometers)	6.76	32
Discharge (cusecs)	27.88	120
Number of Outlets	16	69
Number of Tube wells	195	150
Number of Shallow Wells		58

After verifying the groundwater quality information using Resistivity Survey and Diagnostic Analysis, consents were obtained from the farmers to participate in the project activities. At both the sites, farmers showed interest in participating the project activities, and allowed to use their 4.5 acres of barren land (due to shortage of canal water supplies) for installation of skimming well for supplying groundwater to the drip irrigation system for *bair* orchards. The filed demonstration site near Shahdad Pur comes in the tail area of Lundo minor. The CCA of this minor is 33000 acres. This minor has full supply discharge of 120 cusecs. The canal water supplies had not been reached to the area of project site since many years due to shortage of water. The field demonstration site near Sheikh Barkeo lies within the command area of Kunner II distributary, and presents the case of canal water

shortage as well. This distributary off-takes from the tail reach of Rohri canal, and has CCA of 6790 acres. The full supply discharge of Kunner II distributary is 27.88 cusec (0.79 cumec).

The designs of skimming wells and drip irrigation systems were finalized with the help of Engro-Asahi and the respective landholders. Skimming wells were installed. The lands were prepared; excavations of drip lines and preparation of pits for planting were made. The installation of drip irrigation systems have also completed by the Civic Aabyari, a private organization based in Karachi. This organization has its own manufacturing facility for drip accessories, and is active in promoting drip irrigation system in Sindh with the support and guidance of Engro-Asahi –another private organization. The plantation of *bair* orchard has also been completed during October 2004. At both sites, the *bair* orchards are receiving water directly from the skimming wells. Testing of these systems have also been carried out, and both the systems are working properly. Appendix IV presents the design details of drip irrigation systems to be installed at both the selected sites.

FARMERS FIELD WORKSHOPS

SAFWCO and IIDE have worked on the entire site establishment. For propagating the use of skimming well technology in areas of saline groundwater, farmers will be introduced to these systems through field workshops being planned at the demonstration sites. The SIDA will be also asked to take responsibility to bring farmers (including women farmers) at demonstration sites help promoting the technologies to the wider farming communities in Sindh. The Sindh Agricultural and Forestry Workers Coordinating Organization (SAWFCO), a NGO working in Shahdadpur, will also involved in strengthening the disseminating efforts.

During these field workshops another survey on Socio-Economic Adaptability will be conducted to know the adaptability constraints of the farmers of the area. This survey will identify the percentage of farmers willing to adapt the technology, the estimated area irrigated by the skimming well source pressurized irrigation system, identification of social, economic, cultural and environmental constraints for the adaptability of the technology, farmers' suggestions, issues and options for policy framework and implication.

PROJECT-END WORKSHOP

The project-end workshop will be held at the Mehran University campus with support of IIDE. Provincial policymakers will be invited for extended application of the skimming-well technique in Sindh. Feedback questioner (Appendix V), has already been prepared for the workshop participants, to get their view point on the adaptability of skimming wells pressurized irrigation system in the LIB of Pakistan.

Conclusions and Recommendations

CONCLUSIONS

Based on project activities and their findings, the following conclusions can be drawn:

- The Meander Plain represents soil type responsible for forming fresh groundwater lenses through recharge overlain by native saline groundwater layers. Figure 9 presents the potential areas for skimming wells in different canal commands of the Lower Indus Basin.
- Resistivity Survey (RS) provides a quick and effective mean to ascertain the sub-surface hydro-geological conditions in terms of groundwater quality and the nature of sub-surface materials for the selection of prospective locations for the development of fresh groundwater through the installation of tubewells.
- Majority of the farmers showed interest and trust in this skimming well source drip irrigation system to address their canal water scarcity and groundwater quality constraints. Minority of the farmers believed in 'seeing and believing'; field demonstration sites and adoption of such systems by their fallow farmers would help in motivating these farmers. Only a few farmers showed reluctance, simply due to high installation cost and sophistication. Public-private partnership could help to address their concerns.
- The installation of skimming wells will generate economic activity in saline groundwater areas, where at present groundwater extraction technology is not present. The local pump and related equipments manufacturing industry –to be used in skimming well installation, as well as, the local well drillers and rural laborers –to be engaged in skimming well installation, will benefit from this economic activity. This promisingly cost-effective technology will help poor farmers to install and operate their own wells –thereby improving equity of benefits from groundwater irrigation among the farming community.
- Accurate estimation of groundwater potential, in both the saline groundwater as well as in fresh groundwater areas, will help policymakers and water sector planners to evolve consensus on the sustainable, productive and equitable distribution of canal water resources. This will ensure long-term sustainability of irrigated agriculture in the Indus Basin of Pakistan.
- The ultimate impact of adopting properly designed and operated skimming wells will be on the entire community through increased food security and environmental sustainability. Improved agricultural production through access to groundwater in saline groundwater areas will provide more income to the farmers that will help in improving their livelihoods and reducing poverty. Increased agricultural productivity will also contribute to the national economy.

- The two major environmental problems of the Lower Indus Basin are deteriorating groundwater quality and increasing salinization of agricultural lands. The pumping of large volumes of groundwater from relatively fresh groundwater areas is causing intrusion of saline groundwater into fresh groundwater areas thereby degrading the aquifer. The extensive use of poor quality groundwater for irrigation is adding huge amounts of salts in the root zone, which is aggravating the problem of soil salinity. The project addressed both these environmental issues. Skimming well technology helped in extracting maximum volume of groundwater without occurring saline groundwater upconing and groundwater quality deterioration. The application of this skimmed groundwater using drip irrigation system would help in maintaining productive capacity of the root zone by overcoming problems of soil salinization. Therefore, the successful adoption of these interventions would preserve the resource and will have a positive impact on the environment.
- Water quality parameters responsible for making the water samples marginal were: (i) TDS for Tehsil Hyderabad, Tando Allah Yar and Hala, (ii) TDS and RSC for Tehsil Tando Muhammad Khan and (iii) SAR+RSC for Tehsil Matiari. However, for most of the marginal samples, SAR was not so high to create any considerable problem.
- In whole Hyderabad district, TDS and RSC are causing most of the tubewells water to be Hazardous for irrigation purposes. All other parameter such as, SAR, EC+SAR, EC+RSC, SAR+RSC and EC+SAR+RSC have negligible role to make the pumped water hazardous for irrigation purposes.

RECOMMENDATIONS

Following the conclusions of this project, it is recommended to:

- The primary beneficiaries of this research are over 3 million farmers of the Indus Basin who are largely depending on unsustainable water use patterns to meet their crop water requirements. The adoption of such systems will not only solve environmental constraints, but also provide on demand availability of good quality irrigation water. If government encourages the adoption of skimming well source pressurized irrigation systems, then it would help in increasing crop productivity and improving farmers' livelihood resulting from sustainable conjunctive water use of canal and skimmed groundwater resources.
- The project generated practical scientific knowledge about how to design and operate skimming wells for sustainable extraction of groundwater in the Indus Basin. This problem-solving framework will benefit scientists and intellectual community who will have an increased insight into the processes and practices of skimming wells. The generated scientific knowledge will be equally applicable in other countries, for instance in India, Uzbekistan, Iran, China, and Egypt, facing similar groundwater management issues.

- Most of the tubewells are having shallow depths. Farmers are aware off the thin fresh groundwater lenses overlying the saline groundwater layers a prerequisite for installing skimming wells. The quality of pumped water being marginal and hazardous for irrigation purposes showed that the saline groundwater upconing occurred in these tubewells –this upconing could be avoided using skimming wells.

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Appendix I: Resistivity Survey (RS) results for
various locations in the Lower Indus Basin

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF AFROZE NAZIR AHMED, CHAMBAR.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF SIDDIQUE MEMON, CHAMBAR.

LEGEND (Applicable below watertable conditions)

- Resistivity Zone I <5 ohm-m, ECw >5000 mS/cm
- Resistivity Zone II 5-10 ohm-m, ECw 2500-5000 mS/cm
- Resistivity Zone III 10-15 ohm-m, ECw 2000-2500 mS/cm
- Resistivity Zone IV 15-22 ohm-m ECw 1500-2000 mS/cm
- Resistivity Zone V >22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPRETED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF HABIB-U-RAHMAN SHAIKH, DADU.

LEGEND

(Applicable below watertable conditions)

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF HAKIM MUKHTIAR, GOLARCHI.

LEGEND

(Applicable below watertable conditions)

<div style="display: inline-block; width: 20px; height: 20px; background-color: black; border: 1px solid black;"></div>	Resistivity Zone I	<5 ohm-m, ECw >5000 mS/cm
<div style="display: inline-block; width: 20px; height: 20px; background: repeating-linear-gradient(45deg, transparent, transparent 2px, grey 2px, grey 4px); border: 1px solid black;"></div>	Resistivity Zone II	5-12 ohm-m, ECw 2500-5000 mS/cm
<div style="display: inline-block; width: 20px; height: 20px; background-color: black; border: 1px solid black;"></div>	Resistivity Zone III	12-15 ohm-m, ECw 2000-2500 mS/cm
<div style="display: inline-block; width: 20px; height: 20px; background: repeating-linear-gradient(-45deg, transparent, transparent 2px, grey 2px, grey 4px); border: 1px solid black;"></div>	Resistivity Zone IV	15 - 22 ohm-m ECw 1500-2000 mS/cm
<div style="display: inline-block; width: 20px; height: 20px; background-color: white; border: 1px solid black;"></div>	Resistivity Zone V	>22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF HAJI NAZIR AHMED, JACOBABAD

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGHA KHAN UNIVERSITY SITE, KARACHI.

LEGEND (Applicable below watertable conditions)

Resistivity Zone I	<5 ohm-m, ECw >5000 mS/cm
Resistivity Zone II	5-10 ohm-m, ECw 2500-5000 mS/cm
Resistivity Zone III	10-15 ohm-m, ECw 2000-2500 mS/cm
Resistivity Zone IV	15 -22 ohm-m ECw 1500-2000 mS/cm
Resistivity Zone V	>22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF HAJI MUHAMMAD, KHIPRO.

LEGEND

(Applicable below watertable conditions)

COLUMNAR VIEW OF THE INTERPRETED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF RASOOL BUX LEGHARI, KUNRI.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICAGRICULTURAL FARMS OF ABDUL HABIB , DEH KAK, MIRPURKHAS.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF SHABIR HALEPOTO, MIRPURKHAS

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF CH.AZIZ AHMED, MIRPURKHAS

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF CH. JAVED AHMED, MIRPURKHAS

LEGEND (Applicable below watertable conditions)

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF SHARIF, MIRPURKHAS.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF NASEEM SAHIB, MIRPURKHAS.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF SHABIR HALEPOTO, MIRPURKHAS

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF SHABIR HALEPOTO, MIRPURKHAS

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF NAVEED, MIRWAH GORCHANI

LEGEND

(Applicable below watertable conditions)

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF ANIS MEHMOOD, NAFEEES NAGAR.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF ARBAB ATTAULLAH, NAUKOT.

LEGEND (Applicable below watertable conditions)

Resistivity Zone I	<5 ohm-m, ECw >5000 mS/cm
Resistivity Zone II	5-10 ohm-m, ECw 2500-5000 mS/cm
Resistivity Zone III	10-15 ohm-m, ECw 2000-2500 mS/cm
Resistivity Zone IV	15 -22 ohm-m ECw 1500-2000 mS/cm
Resistivity Zone V	>22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF ABDUL KHALIQUE SHAIKH, NEW SAEEDABAD.

LEGEND (Applicable below watertable conditions)

Resistivity Zone I	<5 ohm-m, ECw >5000 mS/cm
Resistivity Zone II	5-10 ohm-m, ECw 2500-5000 mS/cm
Resistivity Zone III	10-15 ohm-m, ECw 2000-2500 mS/cm
Resistivity Zone IV	15-22 ohm-m ECw 1500-2000 mS/cm
Resistivity Zone V	>22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF ALLAH BACHAYO, NEW SAEEDABAD.

LEGEND (Applicable below watertable conditions)

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF DAIM KHAN RAHOJO, NEW SAEEDABAD.

LEGEND

(Applicable below watertable conditions)

Resistivity Zone I	<5 ohm-m, ECw >5000 mS/cm
Resistivity Zone II	5-10 ohm-m, ECw 2500-5000 mS/cm
Resistivity Zone III	10-15 ohm-m, ECw 2000-2500 mS/cm
Resistivity Zone IV	15-22 ohm-m ECw 1500-2000 mS/cm
Resistivity Zone V	>22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF JAVED SHAIKH, NEW SAEEDABAD.

LEGEND (Applicable below watertable conditions)

Resistivity Zone I	<5 ohm-m, ECw >5000 mS/cm
Resistivity Zone II	5-12 ohm-m, ECw 2500-5000 mS/cm
Resistivity Zone III	12-15 ohm-m, ECw 2000-2500 mS/cm
Resistivity Zone IV	15-22 ohm-m ECw 1500-2000 mS/cm
Resistivity Zone V	>22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF AFTAB AHMED SHAIKH, SAEEDABAD.

LEGEND

(Applicable below watertable conditions)

<div style="width: 20px; height: 20px; background-color: black; display: inline-block;"></div>	Resistivity Zone I	<5 ohm-m, ECw >5000 mS/cm
<div style="width: 20px; height: 20px; background: repeating-linear-gradient(45deg, transparent, transparent 2px, black 2px, black 4px); display: inline-block;"></div>	Resistivity Zone II	5-10 ohm-m, ECw 2500-5000 mS/cm
<div style="width: 20px; height: 20px; background-color: black; display: inline-block;"></div>	Resistivity Zone III	10-15 ohm-m, ECw 2000-2500 mS/cm
<div style="width: 20px; height: 20px; background: repeating-linear-gradient(-45deg, transparent, transparent 2px, black 2px, black 4px); display: inline-block;"></div>	Resistivity Zone IV	15-22 ohm-m ECw 1500-2000 mS/cm
<div style="width: 20px; height: 20px; border: 1px solid black; display: inline-block;"></div>	Resistivity Zone V	>22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF BASHIR AHMED, SHAIKH BARKIO.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF RAJ KUMAR, TALKA JAM NAWAZ ALI.

LEGEND (Applicable below watertable conditions)

Resistivity Zone I	<5 ohm-m, ECw >5000 mS/cm
Resistivity Zone II	5-10 ohm-m, ECw 2500-5000 mS/cm
Resistivity Zone III	10-15 ohm-m, ECw 2000-2500 mS/cm
Resistivity Zone IV	15 -22 ohm-m ECw 1500-2000 mS/cm
Resistivity Zone V	>22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF MUHAMMAD IFTIKHAR, TANDO ADAM.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF HAJI ALI GHULAM, TANDO ALLAH YAR

LEGEND

(Applicable below watertable conditions)

<div style="display: inline-block; width: 20px; height: 10px; background-color: black; border: 1px solid black;"></div>	Resistivity Zone I	<5 ohm-m, ECw >5000 mS/cm
<div style="display: inline-block; width: 20px; height: 10px; background-color: lightgray; border: 1px solid black;"></div>	Resistivity Zone II	5-12 ohm-m, ECw 2500-5000 mS/cm
<div style="display: inline-block; width: 20px; height: 10px; background-color: darkgray; border: 1px solid black;"></div>	Resistivity Zone III	12-15 ohm-m, ECw 2000-2500 mS/cm
<div style="display: inline-block; width: 20px; height: 10px; background-color: mediumgray; border: 1px solid black;"></div>	Resistivity Zone IV	15-22 ohm-m ECw 1500-2000 mS/cm
<div style="display: inline-block; width: 20px; height: 10px; background-color: white; border: 1px solid black;"></div>	Resistivity Zone V	>22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF ALI GHULAM DAL, TANDO ALLAH YAR.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF CHAUDHRY ASIF, TANDO ALLAH YAR.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF AZAM NIZAMANI, TANDO ALLAH YAR

LEGEND

(Applicable below watertable conditions)

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF KHALID IRFAN, TANDO ALLAH YAR.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF MALOOQ NIZAMANI, TANDO ALLAH YAR

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF PIR CHACHAR, TANDO ALLAH YAR

LEGEND (Applicable below watertable conditions)

- Resistivity Zone I <5 ohm-m, ECw >5000 mS/cm
- Resistivity Zone II 5-12 ohm-m, ECw 2500-5000 mS/cm
- Resistivity Zone III 12-15 ohm-m, ECw 2000-2500 mS/cm
- Resistivity Zone IV 15-22 ohm-m ECw 1500-2000 mS/cm
- Resistivity Zone V >22 ohm-m ECw <1500 mS/cm

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF UMED ALI SHAH,TANDO ALLAHYAR

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF ZULFIQAR SHAIKH, TANDO ALLAHYAR.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF CHAUDHRY ASIF, TANDO ALLAHYAR.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF KHALIQUE DINO HALEPOTO, TANDO ALLAHYAR.

LEGEND (Applicable below watertable conditions)

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF MUHAMMAD YOUSIF DAGO, TANDO ALLAHYAR.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF ABDUL MALIK, TANDO JAM.

COLUMNAR VIEW OF THE INTERPERTED SUB-SURFACE HYDROGEOLOGICAL CONDITIONS
ON THE AGRICULTURAL FARMS OF AKHTAR HUSSIAN SHAH, THATTA.

Appendix II: Farmers' Perceptions, Practices
and Problems (PPP) of groundwater
technology

Assessment of Hydro-geological Potential for Skimming Wells in the Lower Indus Basin of Pakistan

Village	
Union Council	
Tehsil/District	
Name of Minor	
Watercourse Number	
Location of WC on Minor	
Surveyor Name	
Survey Date	
Checked by	
<div style="text-align: center;">_____ Supervisor's Signature</div> <div style="text-align: right;">_____ Date</div>	

To Surveyors:

In addition to write specific responses of each question, please try to write important detailed notes (while discussing with the respondent) regarding the PPP of groundwater extracting technologies.

**Assessment of Hydro-geological Potential of Skimming Wells
in the Lower Indus Basin of Pakistan**

**Questionnaire for Survey of Farmers' Perceptions,
Practices and Problems (PPP) of Groundwater
Technologies**

**Water and Power Development Authority (WAPDA)
National Drainage Programme (NDP)
and
International Irrigation Management Institute (IIMI)**

I. RESPONDENTS IDENTIFICATION

- 1.1 Name of the Respondent _____
- 1.2 Father's Name _____
- 1.3 Land ownership¹ (acres) _____
- 1.4 Operational holding² (acres) _____
- 1.5 Culturable waste³ (acres) _____ Since when _____
- 1.6 Reasons for culturable waste
- ☐ High water table ☐ Salinity/Sodicity ☐ Brackish water
- ☐ Scarcity of water ☐ Financial problem ☐ Unleveled land
- ☐ Any other (specify) ☐ Not known
- 1.7 Fallow Land⁴ (acres) Kharif _____ Rabi _____
- 1.8 Salt affected area (acres) _____
- 1.9 Area under orchard (acres) _____
- 1.10 Location of land on selected watercourse
- ☐ Head ☐ Middle ☐ Tail

(NOTE: Please ask about the land area on the selected watercourse)

II. IRRIGATION PROFILE

- 2.1 Source of Irrigation at your farm ☐ Canal only ☐ Tube well only
- ☐ Canal + Tube well ☐ Any other (specify) _____
- 2.2 Total canal irrigation turn time (minutes/acre) _____
- 2.3 How much area is irrigated within allocated time (acres) _____
- 2.4 What is the share of groundwater in total irrigation at your farm? (%) _____
- 2.5 Water table depth (meters) _____
- 2.6 Water Quality (to be measured) 1. EC _____ 2. pH _____
- 2.7 Water Quality (farmer's perception) ☐ Good ☐ Marginal ☐ Poor
- 2.8 Number of owned wells Tube well _____ Skimming well _____
- Any other (specify) _____

III. THECHNICAL DATA REGARDING DIFFERENT TYPES OF WELL

Item	Tube well 1	Tube well 2	Tube well 3
Type of tube well (Tube well/Skimming well)			
Type of ownership (Joint/Exclusive)			
Source of power (Electric/diesel/tractor driven)			
Year of installation			
Specified life (years)			
Capacity (horsepower)			
Depth of bore (feet)			
Diameter of suction pipe (inches)			

Depth of sump (feet)			
Diameter of sump (feet)			
Size of pump (inches)			
Mode of transmission (Belt driven/Monoblock/PTO)			
Discharge (cusec)			
Number of strainers			
Type of strainer (Plastic, other)			
Length of strainer (feet)			
Diameter of strainer (inches)			
Total installation cost (Rs)			
Cost of re-bore (if applicable)			

IV. FARMERS' PERCEPTION REGARDING GROUNDWATER EXTRACTING TECHNOLOGIES

4.1 What is the main reason to install tube well?

4.2 What is the main reason to select the type of shallow well (tube well/skimming well)?

4.3 What is your opinion and experience regarding different types of wells (skimming well tube well)?

V. FARMERS' PRACTICES REGARDING GROUNDWATER EXTRACTING TECHNOLOGIES

5.1 How does you decide the following:

- 5.1.1 Type of tube well

- 5.1.2 Depth of well

- 5.1.3 Diameter of the well

- 5.1.4 Number of strainers (in case of skimming well)

- 5.1.5 Horizontal distance between strainers

- 5.1.6 Size of pump and prime mover

5.2 Does the present tube well fulfill your irrigation requirements without any problem?

☐ Yes

☐ No

5.2.1 If no, what are the reasons?

5.3 Average daily tube well operation (hours) at your farm

Season	Daily Operation Hours		Total Operational Days	
	Slack	Peak	Slack	Peak
Rabi				
Kharif				

5.3.1 Average fuel consumption (liters/hour) _____

5.3.2 Average time spent to irrigate one-acre (hours)
 Tube well only _____ Canal + tube well _____

5.4 What is the average seasonal O&M cost (in Rupees) of tube well?

Season	Item	Seasonal Operational Cost		
		TW 1	TW 2	TW3
Rabi	Electricity bill/Diesel Bill (Rs)			
	Interval of mobil oil change (hours)			
	Cost of mobil oil change (one time)			
	Total M & R Cost (Rs)			
	Any other (specify)			
Kharif	Electricity bill/Diesel Bill			
	Interval of mobile oil change (hours)			
	Cost of mobil oil change (one time)			
	M & R Cost (Rs)			
	Any other (specify)			

5.5 Did you sell tube well water during last year? ☐ Yes ☐ No

5.5.1 If yes, for how many hours and at what rate?

Rabi: Hours _____ Rate (Rs/hour) _____

Kharif: Hours _____ Rate (Rs/hour) _____

5.6 Please provide the following information:

Season	Crop	Area in acres	No. of Irrigations				Yield per Acre
			Total	Canal only	TW only	C+TW	
Rabi	Wheat						
	Rabi Fodder						
	Rabi Veg 1						
	Rabi Veg 2						
	Rabi Veg 3						
	Oilseed						
	Orchard						
	Any other						

Kharif	Cotton						
	Sugarcane						
	Kharif Fodder						
	Kharif Veg 1						
	Kharif Veg 2						
	Kharif Veg 3						
	Oilseed						
	Orchard						
	Any other						

5.7 How does you recognize the water quality at your farm?

5.8 How does you manage or mitigate the water quality of the well at your farm level (in case of poor groundwater quality)?

5.9 How the poor quality of groundwater is affecting the land and crop productivity?

5.10 How does you recognize the salinity/sodicity problem of soil at your farm?

5.11 How does you manage the salinity/sodicity problem of soil at your farm level?

VI. FARMERS' PROBLEMS REGARDING GROUNDWATER EXTRACTING TECHNOLOGIES

6.1 What is the most pinching problem regarding tube well operation?

6.2 How does you manage this problem?

6.3 Are the local experts available to solve your problem?

6.4 What sort of help you need from government to solve your problem?

VII. GENERAL INFORMATION/SUGGESTION

7.1 Are you satisfied with canal water supplies? ☐ Yes ☐ No

7.1.1 If no, what are your comments?

7.2 How does the canal water supplies be improved?

7.3 Are you aware of fresh groundwater layer underlain by marginal to brackish groundwater layer? If yes, please comment?

7.4 What do you know about pressurized irrigation system (skimming well/sprinkler irrigation/trickle or drip irrigation)?

7.5 Are you willing to adapt skimming wells pressurized irrigation system technology?

<End>

NOTE FOR SURVEYORS: Please brief the sample respondent about the skimming well technology and invite him to visit the study sites to see the demonstration of the technology.

CODE BOOK

Question No.	Code	Description
1.6	<ol style="list-style-type: none"> 1 High water table 2 Salinity/Sodicity 3 Brakish water 4 Scarcity of water 5 Financial Problem 6 Unevelled land 7 Any other (Specify) 8 Not known 	
2.1	<ol style="list-style-type: none"> 1 Canal water 2 TW only 3 Canal + TW 4 Any other (specify) 	
4.1	<ol style="list-style-type: none"> 1 Unavailability of water 2 Scarcity of water 	
4.2	<ol style="list-style-type: none"> 1 TW is better for more discharge and Skimming well are not available in market 2 Common practice in the village 3 Skimming Well is not successful /sustainable as compare to TW. 4 Not Known/No comments/Not Applicable 5 Skimming Well is better to pump good quality of groundwater. 6 On the advice of fellow farmer. 	
4.3	<ol style="list-style-type: none"> 1 TW is best, Skimming Well is difficult in tracing technical faults because if one bore is choaked, it is difficult to trace. 2 TW is better in discharge 3 TW has more life of operation as compare to skimming well 4 Common practice in the village/area of installing this type of TW 5 Skimming Well has less life of operation. 	

6 Skimming Well is better to pump good groundwater quality at Shallow depth.
7 Skimming Well has low installation cost as compare to TW.

5.1

- 1 Own will
- 2 Not Known/No comments/Not Applicable
- 3 Mechanics Advice

5.2

- 1 Soil type is sand, so Skimming Well can not satisfy the need of the area
- 2 Area is far away from TW
- 3 Financial problem
- 4 Quality of water is saline
- 5 Fuel is very costly.
- 6 Land is situated at the tail end of WC/minor.
- 7 Due to fragmented/scattered land, we require to install another TW.

5.7

- 1 Through condition of crop
- 2 Taste with tongue
- 3 Not Known/No comments/Not Applicable

5.8

- 1 We shut down the TW in order to avoid further fertility damage.
- 2 Not Known/No comments/Not Applicable
- 3 Mixing with canal water

5.9

- 1 Not Known/No comments/Not Applicable
- 2 Crop did not grow
- 3 Reduction in crop yield
- 4 No impact is seen.
- 5 Land is becoming harder.

5.10

- 1 Not Known/No comments/Not Applicable
- 2 Physical appearance/White colour appears on the surface

5.11

- 1 Not Known/No comments/Not Applicable

- 2 Applying canal water
- 3 We do not cultivated the crop there.
- 4 We cultivate the ganter/rice/other crops resistant to salinity/sodicity.

6.1

- 1 Price of fuel
- 2 Maintenance of foot valve & pump
- 3 Maintenance of engine
- 4 Starting problem of diesel engine.
- 5 Did not face any problem
- 6 Quality of water

6.2

- 1 Not Known/No comments/Not Applicable
- 2 Through collective efforts & calling to Mechanics
- 3 Own efforts

6.3

- 1 Not Known/No comments/Not Applicable
- 2 Yes

6.4

- 1 Provide fuel on credit
- 2 Value of taxes should be reduced
- 3 Electricity should be given on low price.
- 4 Give required amount of irrigation supply for crop.
- 5 Govt. should install TW on head of watercourses.
- 6 Rates of Usher, Dhal and Ahiyana should be decreased.
- 7 Prices of fuel, fertilizers, seeds should be subsidized.
- 8 Not Known/No comments/Not Applicable

7.1

- 1 Minor should be lined.
- 2 Equal distribution throughout the minor.
- 3 Head reachers took our shares also.
- 4 Irregular supply.
- 5 Minor should be desilted.

6 The main canal water supply is low due to drought.
7 Unsatisfactory IPD staff management.

7.2

- 1 Better management.
- 2 Give the designed discharge to reaches.
- 3 Equal distribution of water to all shareholders of the minor.
- 4 Not Known/No comments/Not Applicable
- 5 Water theft should be controlled.

7.3

- 1 Yes
- 2 Through testing of water during installation.
- 3 Not Known/No comments/Not Applicable

7.4

- 1 No
- 2 Little bit

7.5

- 1 Yes
- 2 After seeing the operation of Skimming Well, we will decide.
- 3 Unwillingness
- 4 Not Known/No comments/Not Applicable
- 5 Installation of Skimming Problem depend upon my financial condition.

Socio-Economic Survey of Kunner Minor

Village	Union Council	Tehsil/District	Name of Minor	W/C No.	Location of WC on Minor	Surveyer Name	Date
Haji Mehrab Talpur	Moulan	Hyderabad	Kunner-II	9-R	Tail	Mashooq Ali	19/07/04
Doulat Khan	Moulan	Hyderabad	Kunner-II	10-L	Tail	Mashooq Ali	
Haji Ghulam Brohi	Moulan	Hyderabad	Kunner-II	10-L	Tail	Mashooq Ali	
Mir Mushtaque Talpur	Moulan	Hyderabad	Kunner-II	10-L	Tail	Mashooq Ali	
Gul Lashari	Moulan	Hyderabad	Kunner-II	2-R	Head	Mashooq Ali	20/07/04
Ch. Abdul Ghafoor	Moulan	Hyderabad	Kunner-II	9-AL	Middle	Mashooq Ali	
Wagodar	Khokhar	Hyderabad	Kunner-II	9-AL	Middle	Mashooq Ali	
Wagodar	Khokhar	Hyderabad	Kunner-II	9-AL	Middle	Mashooq Ali	
Ch. Abdul Ghafoor	Moulan	Hyderabad	Kunner-II	9-AL	Middle	Mashooq Ali	
Ch. Abdul Ghafoor	Moulan	Hyderabad	Kunner-II	9-AL	Middle	Mashooq Ali	
Gul Lashari	Moulan	Hyderabad	Kunner-II	2-AR	Head	Mashooq Ali	
Gul Lashari	Moulan	Hyderabad	Kunner-II	2-R	Head	Mashooq Ali	
Gul Lashari	Moulan	Hyderabad	Kunner-II	2-R	Head	Mashooq Ali	
Jhan Mori	Moulan	Hyderabad	Kunner-II	2-R	Head	Mashooq Ali	
Mohd. Tahir Soonaro	Moulan	Hyderabad	Kunner-II	1-R	Head	Mashooq Ali	
Malook Pitafi	Moulan	Hyderabad	Kunner-II	1-R	Head	Mashooq Ali	
Khan Mohammad	Moulan	Hyderabad	Kunner-II	1-R	Head	Mashooq Ali	37994
Nagar Khan Wasan	Tando Qaiser	Hyderabad	Kunner-II	1-R	Head	Mashooq Ali	
Nagar Khan Wasan	Tando Qaiser	Hyderabad	Kunner-II	1-R	Head	Mashooq Ali	
Dado Pitafi	Moulan	Hyderabad	Kunner-II	2-R	Head	Mashooq Ali	
Mohd. Tahir Soonaro	Moulan	Hyderabad	Kunner-II	5-AR	Middle	Mashooq Ali	19/07/04
Haji Mehrab Talpur	Moulan	Hyderabad	Kunner-II	5-AR	Middle	Mashooq Ali	
Haji Mehrab Talpur	Moulan	Hyderabad	Kunner-II	5-AR	Middle	Mashooq Ali	
Haji Mehrab Talpur	Moulan	Hyderabad	Kunner-II	10-L	Tail	Mashooq Ali	
Gamardin Lakho	Moulan	Hyderabad	Kunner-II	9-L	Tail	Mashooq Ali	
Haji Khan Jamali	Moulan	Hyderabad	Kunner-II	10-L	Tail	Mashooq Ali	
Ch. Abdul Ghafoor	Moulan	Hyderabad	Kunner-II	10-L	Tail	Mashooq Ali	
Suleman Rajput	Moulan	Hyderabad	Kunner-II	10-L	Tail	Mashooq Ali	

Name	Father's Name	Land Ownership (Acres)	Operational Holding (Acres) (Acres)	Culturable waste (Acres) (Acres)	Since When
Mumtaz Ali	Nabi Bux Talpur	15	12	3	1994
Rahim Bux	Haji Ahmad Khoso	10.5	10.5	0	0
Haji Ghulam Brohi	Walidad Brohi	16	11	5	2003
Ilamdin Lakho	Karamdin	70	70	20	1980
Kamal Khan	Qaim Kham Lashari	21	21	0	0
Mohd. Ismael	Nathe Khan Rajput	70	106	14	2002
Ali Ahmad	Piyaro Lashari	45	45	8	1998
Piyar Ali	Haji Ranjho Lashari	55	55	0	0
Mohd. Ismael	Nawabdin Rajput	60	60	0	0
Islam-u-din	Kamal Din	30	30	0	0
Ali Ahmad	Ghazi Khan	54	26	0	0
Mir Mohd.	Haji Misri Lashari	100	118	0	0
Alam Khan	Mohd. Rahim	6	12	0	0
Haji Ahmad Zanoor	Allah Bux	30	50	2	1997
Bux Ali	Mohd. Usman	11	6	0	0
Zanwar Mohd. Hasan	Nabi Bux	46	23	4	2002
Khan Mohammad	Liaquat Pitafi	28	20	2	1997
Jan Mohammad	Mohammad Juman	15	28	3	1993
Noor Mohammad	Khuda Dino	35	28	0	0
Shafee Mohammad	Bacho Khan	10	7	0	0
Aijaz Ali	Likhodino Soonaro	27	30	1	1985
Fayaz Ali	Ali Mohammad	35	18	4	1998
Ghulam Akbar	Budho Khan	12	8	0	0
Mohd. Bachal	Faiz Mohd.	34	31	0	0
Mohd. Juman	Ali Mohammad	30	27	0	0
Haji Khan Jamali	Punhal Khan	24	16	1	2002
Mohd. Siddique	Mohd. Sabir	2	10	0	0
Gulzar Khan	Akbar Khan	50	52	4	1990

Name	Father's Name	Reasons for Culturable waste	Fallow Land (acres) Kharif	Rabi (Acres)	Salt Affected Area (Acres)	Area Under Orchard (Acres)
Mumtaz Ali	Nabi Bux Talpur		5	7	8	0
Rahim Bux	Haji Ahmad Khoso		0	5	5	0
Haji Ghulam Brohi	Walidad Brohi		4	7	6	0
Ilamdin Lakho	Karamdin		6	20	20	4
Kamal Khan	Qaim Kham Lashari		0	2	10	7
Mohd. Ismael	Nathe Khan Rajput		4	58	73	4
Ali Ahmad	Piyaro Lashari		4	24	29	4
Piyar Ali	Haji Ranjho Lashari		0	23.5	23.5	0
Mohd. Ismael	Nawabdin Rajput		0	21	30	4
Islam-u-din	Kamal Din		0	7.5	0	4
Ali Ahmad	Ghazi Khan		0	0	4	0
Mir Mohd.	Haji Misri Lashari		0	18	18	16
Alam Khan	Mohd. Rahim	2,4	0	4	6.5	0
Haji Ahmad Zanoor	Allah Bux		0	2.5	2.5	6
Bux Ali	Mohd. Usman		2	5.75	2.75	2
Zanwar Mohd. Hasan	Nabi Bux		2	23	23	4
Khan Mohammad	Liaquat Pitafi		4	16	18	2
Jan Mohammad	Mohammad Juman		0	4	4	3
Noor Mohammad	Khuda Dino		0	7	19	3
Shafee Mohammad	Bacho Khan		5	3	6	2
Aijaz Ali	Likhodino Soonaro		4	9	20	1
Fayaz Ali	Ali Mohammad		0	17	20	4
Ghulam Akbar	Budho Khan		0	4	4	0
Mohd. Bachal	Faiz Mohd.		0	4	3	4
Mohd. Juman	Ali Mohammad		4	3	4	4
Haji Khan Jamali	Punhal Khan		0	8	8.5	0
Mohd. Siddque	Mohd. Sabir		4	2	2	0
Gulzar Khan	Akbar Khan		0	11	4	0
			4			

Name	Father's Name	Location of Land on Selected WC 1=Head, 2=Middle, 3=Tail
Mumtaz Ali	Nabi Bux Talpur	3
Rahim Bux	Haji Ahmad Khoso	2
Haji Ghulam Brohi	Walidad Brohi	2
Ilamdin Lakho	Karamdin	3
Kamal Khan	Qaim Kham Lashari	1
Mohd. Ismael	Nathe Khan Rajput	1
Ali Ahmad	Piyaro Lashari	3
Piyar Ali	Haji Ranjho Lashari	3
Mohd. Ismael	Nawabdin Rajput	2
Islam-u-din	Kamal Din	3
Ali Ahmad	Ghazi Khan.	2
Mir Mohd.	Haji Misri Lashari	2
Alam Khan	Mohd. Rahim	1
Haji Ahmad Zanoor	Allah Bux	2
Bux Ali	Mohd. Usman	3
Zanwar Mohd. Hasan	Nabi Bux	3
Khan Mohammad	Liaquat Pitafi	3
Jan Mohammad	Mohammad Juman	1
Noor Mohammad	Khuda Dino	1
Shafee Mohammad	Bacho Khan	2
Aijaz Ali	Likhodino Soonaro	3
Fayaz Ali	Ali Mohammad	3
Ghulam Akbar	Budho Khan	3
Mohd. Bachal	Faiz Mohd.	3
Mohd. Juman	Ali Mohammad	2
Haji Khan Jamali	Punhal Khan	1
Mohd. Siddque	Mohd. Sabir	3
Gulzar Khan	Akbar Khan	1

Name	Father's Name	Source of Irrigation	Total canal turn time (minutes/acres)	Area is irrigated with allocated time (Acres)	
Mumtaz Ali	Nabi Bux Talpur	2	25	0	0
Rahim Bux	Haji Ahmad Khoso	3	25	1	2.8
Haji Ghulam Brohi	Walidad Brohi	3	35	6	6
Ilamdin Lakho	Karamdin	3	15	4	4
Kamal Khan	Qaim Kham Lashari	3	20	15	15
Mohd. Ismael	Nathe Khan Rajput	3	20	8	8
Ali Ahmad	Piyaro Lashari	3	20	10	10
Piyar Ali	Haji Ranjho Lashari	3	20	12	12
Mohd. Ismael	Nawabdin Rajput	3	20	8	8
Islam-u-din	Kamal Din	3	15	24	24
Ali Ahmad	Ghazi Khan	3	15	2	2
Mir Mohd.	Haji Misri Lashari	3	15	8	8
Alam Khan	Mohd. Rahim	3	20	3	3
Haji Ahmad Zanoor	Allah Bux	3	15	8	8
Bux Ali	Mohd. Usman	3	15	5	5
Zanwar Mohd. Hasan	Nabi Bux	3	15	5	5
Khan Mohammad	Liaquat Pitafi	3	15	6	6
Jan Mohammad	Mohammad Juman	3	15	3	3
Noor Mohammad	Khuda Dino	3	25	7	7
Shafee Mohammad	Bacho Khan	3	15	9	9
Aijaz Ali	Likhodino Soonaro	3	20	3	3
Fayaz Ali	Ali Mohammad	3	20	9	9
Ghulam Akbar	Budho Khan	3	20	0	0
Mohd. Bachal	Faiz Mohd.	2	30	0	0
Mohd. Juman	Ali Mohammad	2	15	5	5
Haji Khan Jamali	Punhal Khan	3	25	8	8
Mohd. Siddque	Mohd. Sabir	3	25		
Gulzar Khan	Akbar Khan	3	25		

Name	Father's Name	Share of GW in total irrigation (%)	Water Table depth (Ft)	Water Quality EC	pH	Water Quality (Perception)
Mumtaz Ali	Nabi Bux Talpur	100	25			1
Rahim Bux	Haji Ahmad Khoso	55	45			2
Haji Ghulam Brohi	Walidad Brohi	80	35	1400		1
Ilamdin Lakho	Karamdin	98	40			1
Kamal Khan	Qaim Kham Lashari	65	28	1500	7.4	1
Mohd. Ismael	Nathe Khan Rajput	60	34	1000		1
Ali Ahmad	Piyaro Lashari	80	35			1
Piyar Ali	Haji Ranjho Lashari	80	40			1
Mohd. Ismael	Nawabdin Rajput	80	40	1100	7.6	1
Islam-u-din	Kamal Din	70	37			1
Ali Ahmad	Ghazi Khan	80	40			1
Mir Mohd.	Haji Misri Lashari	50	30	500	8	1
Alam Khan	Mohd. Rahim	65	28	1200	7.8	1
Haji Ahmad Zanoor	Allah Bux	60	20			1
Bux Ali	Mohd. Usman	80	20			2
Zanwar Mohd. Hasan	Nabi Bux	60	20			1
Khan Mohammad	Liaquat Pitafi	80	20			2
Jan Mohammad	Mohammad Juman	60	12			2
Noor Mohammad	Khuda Dino	80	12			1
Shafee Mohammad	Bacho Khan	70	35			1
Aijaz Ali	Likhodino Soonaro	50	20			1
Fayaz Ali	Ali Mohammad	100	20			2
Ghulam Akbar	Budho Khan	50	20			1
Mohd. Bachal	Faiz Mohd.	80	20			1
Mohd. Juman	Ali Mohammad	100	40	2100	8	1
Haji Khan Jamali	Punhal Khan	100	39	1300	7.4	2
Mohd. Siddique	Mohd. Sabir	80	40			1
Gulzar Khan	Akbar Khan	55	43			1

Name	Father's Name	No. of owned wells		SW Others	
		TW		SW	Others
Mumtaz Ali	Nabi Bux Talpur		1	0	0
Rahim Bux	Haji Ahmad Khoṣo		1	0	0
Haji Ghulam Brohi	Walidad Brohi		1	0	0
Ilamdin Lakho	Karamdin		1	0	0
Kamal Khan	Qaim Kham Lashari		3	0	0
Mohd. Ismael	Nathe Khan Rajput		1	0	0
Ali Ahmad	Piyaro Lashari		2	0	0
Piyar Ali	Haji Ranjho Lashari		2	0	0
Mohd. Ismael	Nawabdin Rajput		1	0	0
Islam-u-din	Kamal Din		1	0	0
Ali Ahmad	Ghazi Khan		3	0	0
Mir Mohd.	Haji Misri Lashari		0	0	0
Alam Khan	Mohd. Rahim		1	0	0
Haji Ahmad Zanoor	Allah Bux		1	0	0
Bux Ali	Mohd. Usman		1	1	0
Zanwar Mohd. Hasan	Nabi Bux		1	1	0
Khan Mohammad	Liaquat Pitafi		1	0	0
Jan Mohammad	Mohammad Juman		1	0	0
Noor Mohammad	Khuda Dino		0	1	0
Shafee Mohammad	Bacho Khan		1	0	0
Aijaz Ali	Likhodino Soonaro		0	1	0
Fayaz Ali	Ali Mohammad		1	0	0
Ghulam Akbar	Budho Khan		0	1	0
Mohd. Bachal	Faiz Mohd.		1	0	0
Mohd. Juman	Ali Mohammad		2	0	0
Haji Khan Jamali	Punhal Khan		1	0	0
Mohd. Siddque	Mohd. Sabir		1	0	0
Gulzar Khan	Akbar Khan		2	0	0

Name	Father's Name	Type of TW 1=TW, 2=SW	Type of Ownership 1=Exclusive, 2=Joint	Source of Power 1=Electric, 2=Diesel, 3=Tractor	Year of Installation	Specified Life (Years)
Mumtaz Ali	Nabi Bux Talpur	1	1	1	1988	20
Rahim Bux	Haji Ahmad Khoso	1	2	2	2000	10
Haji Ghulam Brohi	Walidat Brohi	1	1	1	2001	10
Ilamdin Lakho	Karamdin	1	1	1	2003	15
Kamal Khan	Qaim Kham Lashari	1	2	2	1998	6
Mohd. Ismael	Nathe Khan Rajput	1	1	1	1997	6
Ali Ahmad	Piyaro Lashari	1	1	1	1996	10
Piyar Ali	Haji Ranjho Lashari	1	2	2	1975	3
Mohd. Ismael	Nawabdin Rajput	1	2	2	1975	8
Islam-u-din	Kamal Din	1	1	1	1995	11
Ali Ahmad	Ghazi Khan	1	1	1	1992	10
Mir Mohd.	Haji Misri Lashari	1	1	1	2000	10
Alam Khan	Mohd. Rahim	1	2	2	2001	10
Haji Ahmad Zanoor	Allah Bux	1	1	1	1998	13
Bux Ali	Mohd. Usman	1	1	1	2002	15
Zanwar Mohd. Hasan	Nabi Bux	2	1	1	2001	5
Khan Mohammad	Liaquat Pitafi	2	1	1	2001	4
Jan Mohammad	Mohammad Juman	1	1	1	2001	10
Noor Mohammad	Khuda Dino	1	1	1	2000	13.5
Shafee Mohammad	Bacho Khan	2	1	1	2002	10
Aijaz Ali	Likhodino Soonaro	1	1	1	2000	17.5
Fayaz Ali	Ali Mohammad	2	1	1	2001	10
Ghulam Akbar	Budho Khan	1	1	1	2000	15
Mohd. Bachal	Faiz Mohd.	2	1	1	2000	5
Mohd. Juman	Ali Mohammad	1	2	2	1980	10
Haji Khan Jamali	Punhal Khan	1	1	1	2001	15
Mohd. Siddque	Mohd. Sabir	1	2	2	1997	10
Gulzar Khan	Akbar Khan	1	2	2	2000	20