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M.Eng Project
SCARP Analysis

Title: Analysis of Salinity Control and Reclamation Project in Pakistan

<u>Objective</u>: The main objective of this report is to understand how Pakistan can increase or maintain water quantity for irrigation because water is generally a limiting factor for agricultural growth in the country. Critical to accomplishing this task is developing a strategy is needed to allow pumping fresh water without interference from the salty groundwater below fields. This will require a review of the status of the SCARP wells installed about 50 years ago. These wells became too expensive for the government to operate so some of them have been taken over by farmers and many abandon.

A. Review current situation and approaches to prevent pumping of saline water onto fields
B. Increase or maintain water quantity
C. Analysis of SCARP wells from 1960's to present
D. Identifying potential solutions or improvements

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Problem Definition: The waterlogging and salinity problems have long existed in Pakistan and are still present in the Indus River Basin region of Pakistan. Approximately, 6 million ha of soil is affected with salt and of that 2.7 million ha lies in Punjab, which produce more than 90% of the country's food. Additionally, 1 million ha of land is affected by waterlogging. The salinity problem has become worse because of secondary salinization associated with the usage of shallow groundwater tables and poor quality groundwater. Every year, 40,000 ha of land become abandoned in the Indus Basin because of secondary salinization (cite). In addition, secondary salinization is causing waterlogging problems. Approximately, 25% of the irrigated area in the Punjab province is classified as severally waterlogged and 60% of the irrigated area of the Sindh providence [Quereshi, 2009]. This poses a huge problem to the people of Pakistan since agriculture is its largest source of revenue.

Numerous approaches have been developed to stop the twin menace problems of salinity and waterlogging. Large-scale tubewells knows as Salinity Control and Reclamation Project (SCARP) wells were developed throughout Pakistan. The program continued from 1960's-2000; it covered 8 million ha of land and cost approximately $2 billon [Quereshi, 2009]. It provided the newly built Pakistan with an opportunity to build its agriculture. However, the SCARP wells have benefits and shortcomings. Due to these issues, it is becoming critical for Pakistani farmers to find successful ways to irrigate saline soil and increase crop yield without extracting too much water.

SCARP Background

The SCARP wells project started in 1961 with 2,100 public tubewells to provide drainage for over 0.6 million ha land in Punjab. The wells extrapolated water out of the ground to control the groundwater table. The water was placed into three different locations depending on the quality of the water. For example, suitable fresh groundwater was transferred to canals for irrigation purposes, moderately saline water was mixed with canal water for irrigation, and saline water was dumped into the reservoir to evaporate [WAPDA, 2015].

The SCARP wells eliminated the waterlogging problems in the projected area and a total of 60% of saline classified land was reclaimed. Additionally, the SCARP wells double the amount of water for irrigation, which increased the cropping intensity by 50 percent. SCARP wells not only eliminated the double menace problem of Pakistan, but it also increased agricultural productivity. Thus, the installation of SCARP wells continued with covering 3.7 million ha of land. However, many specialists in 1960's started questioning installation of SCARP wells in areas that already had significant fresh groundwater available. On the other hand, the policymakers continue to support the expansion of the SCARP wells, which created difference between the experts in the salinity and waterlogging issues and the policymakers [Bhatti, 1987].

The problems with the SCARP wells started a decade later. In the late 1970's, the government could no longer afford operating the SCARP wells because 40 percent of non-development budget was being subsidized for the SCARP wells. In addition, in some areas, SCARP wells drew saline water to the surface, which created waterlogging problem and the capacity of SCARP tubewells decreased by 40 percent [Quershi, 2014]. Also, electricity supply for the wells started running short. Pakistan government believed the centralized system of SCARP wells was the major issue in its operation [Bhatti, 1987].

Hence in 1977, SCARP wells VI phase took place, which dealt with supporting privatized tubewells by offering farmers credit for constructing wells and subsidies on electricity in areas where plentiful groundwater was available. The privatized tubewells were believed to reduce the salinity problem. The SCARP tubewells were about 40-120 m deep with discharge capacity of 60-140 liters per second, compared to the privatized tubewells, which are much shallower with discharge capacity from 7-28 liters per second. Hence, the discharge from private tubewells is much cheaper where water table is lower than 10 m. The tubewells draw better-quality groundwater from the upper part of the aquifer, which reduces the salt buildup in the soil. Soil salinity is a widespread issue in Pakistan, privatized tube wells may seem a quick solution to the problem, but can actually exacerbate the problem over time. There is no guarantee water table will remain stable because thousands of private tubewells are being operated without any coordination[1][Riztme, 2007][Quereshi, 2009].

In 1979, the World Bank offered funds to Pakistan for improving watercourses, and rebuilding the irrigation and drainage system. From the 1980's to 1990's, SCARP "horizontal drainage" subsurface pipes were installed in areas with saline groundwater[2]. The subsurface drainage consists of buried collector and field drains. Most of the subsurface drainage requires discharge into a sump[3] because areas with the twin menace are flat regions in Pakistan. The depths of these drains are kept at a depth well below the root zone for two reasons: to reduce salinization of the root zone that resulted from capillary rise and secondly deeper systems were cheaper because deeper drains allow larger drain space [Ghumman 2012].

These SCARP Wells projects were transferred to the Water and Power Department Authority (WAPDA), who then transferred them over to the provincial departments [Inam, 2015]. This became problematic because the provincial government did not

[1] Current problems with tubewells are discussed in later part of the report.
[2] Private tubewells were installed in areas with better groundwater quality
[3] Once the water is collected from the sump it is discharge into open drainage network source: Ghumman, 2012

have any budget to operate the SCARP wells. The government of Pakistan was already facing issues with managing the operations cost of the SCARP wells. In theory, giving the provincial government the authority of the SCARP wells was intended to decentralize the system, however due to insufficient budget to operate the wells led to deterioration of the SCARP wells. The provincial government tried to sell the SCARP wells to the local farmers, but many farmers refused to purchase them because they were unable to afford the operations' cost of the wells, and they saw more benefit in privatized tubewells [Ghumman, 2012]. Two subsurface SCARP wells are evaluated in this paper.

Evaluation of SCARP Wells

The fourth drainage project (FDP) was installed in Faisalabad, Pakistan where the area suffered both from salinity and waterlogging. The FDP drainage was set up to improve the main drainage system. The design of the drainage was to carry maximum amount of slit away from the area of crop production. Additionally, banks were provided to guide possible overland flow to the proper inlets of the drain. 125 wells spaced 4 to 5 km apart were installed to observe monthly changes in the water table. The results indicated that improvement in main drainage led towards improvement in the water table. The first installation of subsurface occurred in 1985, which lowered the water table in the FDP region [Ritzema, 2007]. Soil salinity also decreased in the areas where subsurface pipes were installed. From the years of 1984 to 2000, the salt free area increased from 56% to 73%. Thus, the overall improvement was 17% [Figure 1][Azhar, 2010][Appendix I]. The improvement is mainly due to leaching of the salt below 180 cm depth by lowering the water table. During the SCARP wells operation, the crop yield increased 11 to 14 percent because more fresh water became available through the SCARP projects [Azhar, 2011].

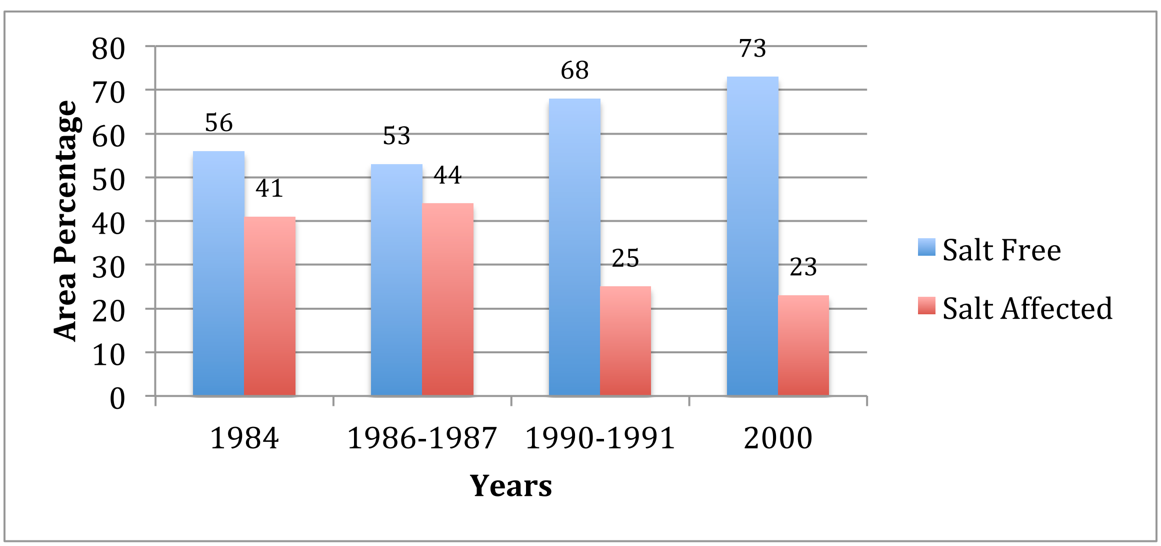

Figure 1: Soil Profile in FDP Area source: [Azhar, 2010]

Post SCARP

As of 2000, the SCARP wells discontinued in the area because of poor performance, high costs, and short operational life associated with the infrastructure. The Government of Pakistan encourages installation of tubewells to reduce waterlogging problems. For example, the government provides subsidies for the farmers to install tubewells. Also, there is no restriction on usage and installation of tubewells; thus, the tubewells are easily available for the farmers to install [Quershi,2014].

In the FDP SCARP region, rapid increase of tubewells occurred, which resulted in deteriorating groundwater quality and declining groundwater. According to the Pakistan's International Waterlogging and Salinity Research Institute, the watershed near the FDP location is recognized as hazardous with electrolyte above 1500ppm. As a result, secondary salinization is a major problem in the area because farmers are using the marginal–quality groundwater for irrigation. Furthermore, all the stakeholders in the Rechna Doab[4] region agreed salinity problem was due to unequal distribution of the water, which caused farmers to use marginal quality groundwater to irrigate crops [Inam, 2014]. Figure 2 and figure 3 show increase in soil salinity and rise of water table, which is causing salinity problems.

The unequal water distribution problem refers to the warabandi system, which was designed a century ago to distribute water to the farmers. The warbandi system has become a problem because population of farmers has increased and the irrigated area has not. Farmers at the tail end of the canal system do not receive the same amount and quality of water as the farmers at the head of the canals. The tail end farmers tend to belong to lower financial status. Thus, salinization problem in Pakistan is based on geographic location and infrastructure issues.

In Rechna Doab, post FDP SCARP Wells tubewells increased to prevent waterlogging and the use of marginal groundwater. During the functional period of the SCARP wells from 1984 to 2000, a reduction in salinity and water logging issues was seen. Once the SCARP Wells closed operations, both the salinity and waterlogging problems continued and gave rise to additional problems in the area such as reduction of water for the poor farmer, increase of tubewells, and the usage of poor quality water. If salinity and waterlogging issues continue to rise, Pakistan's cultivated land will be reduced.

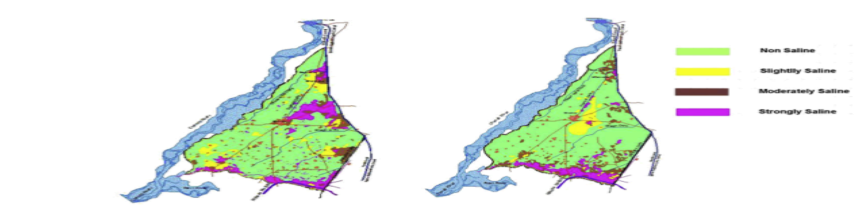

Figure 2: Changes in soil surface salinity based on USDA standards in Rechna Doab area part of FDP SCARP projects source: Inam 2015

[4] Rechna Doab is a part of the FDP SCARP Projects

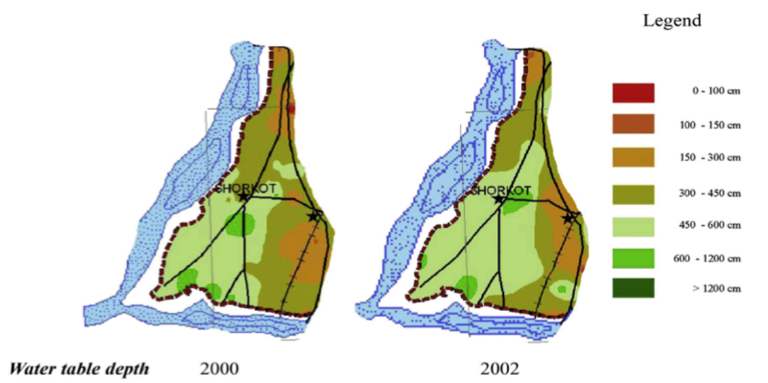

Figure 3: Changes in water table depth in Rechna Doab area part of FDP SCARP projects source: Inam 2015

<u>Sindh SCARP wells evaluation:</u>
East Khaipur drainage in Sindh was also placed to combat problems with waterlogging and salinity. The project covered 18,000 ha of the Sindh Province of which 14,000 ha consist of subsurface drainage. Horizontal polyethylene pipes were installed for dewatering the area, which became highly expensive [Ritzema, 2007]. Post-SCARP project analysis was not found on this area.

The Mirpurkhas title drainage project (MKDP) occurred from years of 1994 to 1997 in the Sindh Province. Studies of salinity profile post project were only available from years 2000 to 2002. In 2000, total of 65 percent area of the MKDP was considered salt affected and in 2001 only 35 percent was consider salt affected. A total of 20 percent reduction from year 2000 to 2001 is observed, but only 14 percent reduction occurred in 2000 compared to 2002. The variation in results between 2001 and 2002 are due to poor management and operation of the drainage system [Azhar, 2010, figure 4][5]. These findings indicate that operations problems can contribute towards increase in salinity, which can cause severe agricultural

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[5] Non-Saline Non-Sodic (NS-NS) refers to Electricity Conductivity (EC) <4 Sodium Absorption Ratio (SAR) <13; Saline Non-Sodic (S-NS) refers to EC>4; SAR <13; and Saline Sodic (S-S) ECe > 4; SAR > 13. These methods are used to describe the soil salinity profile (Source: Azhar 2010).

problems. If there is a management issue with the SCARP Wells, the problem of salinity and waterlogging can increase without being noticed. The operation of SCARP wells system is centralized towards one system, but it affects the entire region. If the problem of operational management continues in the region, salinity problems become worse and poor farmers will suffer in agricultural growth. Thus, a solution that decentralized the SCARP well system needs to be implemented[Appendix I].

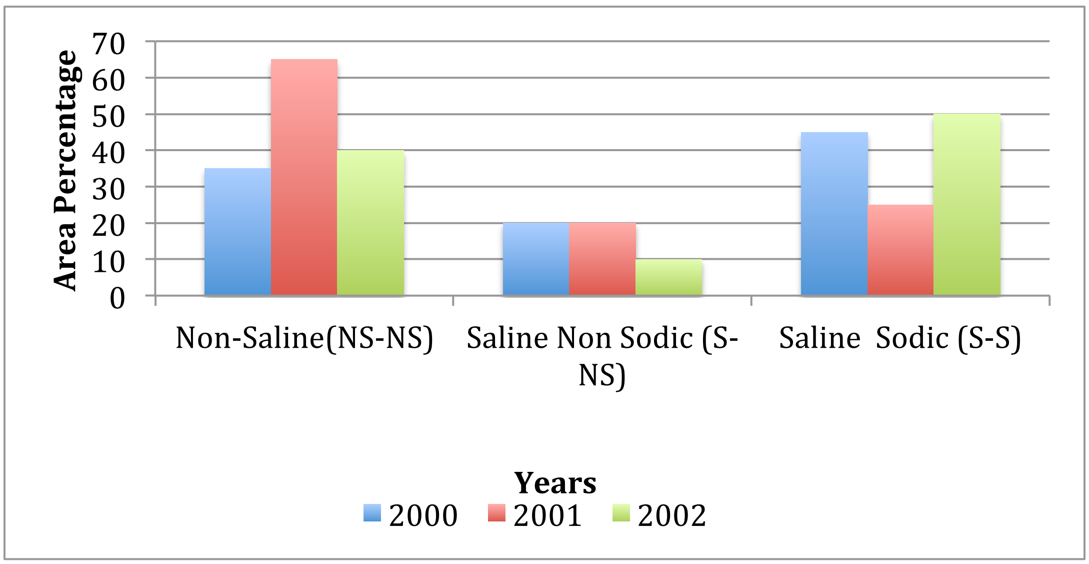

Figure 4: Soil Profile in MDKP SCARP Area Source: Azhar 2010

Problems with SCARP

The SCARP wells have proven to reduce salinity in the region, but they were not a long-term solution for the Pakistani farmers. First, the cost of operations and maintenance of SCARP Wells became expensive for the country to maintain. Then, the projects were passed down towards the power & irrigation departments, who passed them to the provincial government. After few years of operations, SCARP Wells in some areas increased salinity and raised the water table [World Bank]. Studies indicate farmers lost interest in SCARP Wells because fifty percent of SCARP policies made did not involve the stakeholders. In addition, the SCARP Wells projects caused growth in weeds on the surface and subsurface drains, which led towards standing stagant water to accumulate on agricultural land [Inam, 2015].

The SCARP wells reported above are in regions of semi-arid and arid climate, which have both the waterlogging and salinity problems. Both areas have the same issues, increasing population and decreasing water supply. Irrigating the land to provide agriculture for the people will become a challenge for the areas in the future. SCARP wells provide only a short term solution to decrease the salinity problem. In the saline groundwater areas, the SCARP did not properly lower the water table depth [World Bank]. The main problem of seepage from canal water remains unsolved. New drainage systems are not designed or may not be feasible in the flat region. Current data for Faisalabad and Sindh SCARP Wells area is unavailable. From the findings of SCARP wells, it can be inferred waterlogging and salinity problems have remained the same or became worse over the years.

Resolutions:

The key steps for reclamation in Pakistan are lowering of the water table, leaching excess salt out of the root zone, and attending satisfactory water infiltration and scientific management of the soil [Quershi, 2008]. Implementation of SCARP wells has taught new application process to be cost effective and sustainable in Pakistan. As stated earlier, policy making of SCARP wells left out the main stakeholders, including the farmers, from the process. This caused problems with the ownership and management of the SCARP wells. A resolution needs to be implemented that preserves the current water supply and reduces soil salinity. Also, it is important for the solution to involve the farmers' perspective and be economically feasible for them. Most importantly, studies indicate, based on Pakistan's low water supply, that it is better to improve irrigation methods. Furthermore, improvements in irrigation methods will decrease the need for subsurface drainage system [Ritzema, 2007].

Such improvement in irrigation system includes planting salt-tolerant tress and salt tolerant bushes, using agricultural and industry manure, using gypsum, and applying biodrainage methods [Quershi, 2008]. Additionally, involving farmers and understanding their opinions would be critical in changing the irrigation system. The older techniques that farmers applied to reduce salinity was ignored during the implementation of SCARP wells. These techniques should be studied to understand how they work and how they can be applied. Irrigation recommendations are made based on literature research and local perspective. To create such a solution, older farmers and local engineers from the FDP region were interviewed to gain a better understanding of their perspective.

Local Sample Solution

Farmer-1 (Muhammad Sharif): Upon speaking with a local farmer in the FDP area, he indicated he prefers using older methods to reduce the salinity problems. This methodology involves using of animal and human waste along with rotten onion and corn placed in the soil. The farmer indicated, after two weeks, the soil returns to its original state and becomes richer in nutrient. The methodology was used until 1970's, but with the increase of commercial fertilizers farmers stopped applying natural waste. From the farmers' perspective, applying human waste and rotten onions or corn was cheaper and more time efficient. Additionally, a farmer indicates this methodology was successful, but they did not know how much can be applied or why it worked. Sometimes adding inaccurate amount of waste did not reduce the salinity problem. An application of this methodology has not been applied.

Farmer-2 (Hammed Reza): Mr. Reza mentioned animal manure and salt tolerant crops are the most useful techniques because they accumulated salt and have a resale value. He explained animal manure provides his land with better nutrients. Mr. Reza explained an older technique to reduce salinity from the subsurface was to apply old salt tolerant crops on the ground. The crops were decomposed and placed into the ground before harvesting period. Mr. Reza explained that he applied this methodology earlier on his farm before tubewells became available. Nowadays, the farmer uses flood irrigation method to reduce salinity from soil because of easy access to water through tubewells. These tubewells are becoming increasingly expensive because they need to be built going deeper into the ground. Additionally, Mr. Reza mentioned having a large portion of trees cut down near his farm and he would like to see more trees being planted. Furthermore, he mentioned the use of animal manure is becoming an increasingly popular practice on his farm because it provides nutrients and decreases salt level in the ground.

Irrigation Engineer (Tallal Khan): Local engineers from Pakistan's Punjab region were interviewed to get a better understanding of the salinity problem and methodology that can be developed to reduce the salinity problem. The modern techniques being applied in Pakistan are usage of animal manure, bed irrigation, gypsum, flood irrigation, and pressurized irrigation. The overall change the engineer has noticed is the increased usage of flood irrigation, which Mr. Khan think is not a sustainable practice for Pakistan. He mentioned for the past two decades, water availability has decreased, which decreased the surface water availability. Many farmers started using tubewells, which is causing groundwater depletion. Furthermore, Mr. Khan recommends for Pakistani farmers to shift away from flood irrigation and increase usage of biomass. Mr. Khan explained using biomass will require less water and decrease salinity from the soil.

Researcher (Qaiser Masood): Upon speaking with a researcher at Faisalabad Agricultural University, he indicates modern techniques that are being applied to decrease salinity from the soil surface. These techniques include using flood, pressurized, ridge, and sprinkler irrigation. The researcher mentions using ridge irrigation methodology as the most effective technique because the salt accumulates in the center and requires 20-75 percent less water compared to existing irrigation.

Most importantly, the researcher also mentions changing irrigation methodology would be the most effective way to reduce salinity from the soil. This methodology includes planting bio drainages such as the Eucalyptus. He mentioned eucalyptus as being one of the most effective biodrainage and there is a lot of literature on the effective use of eucalyptus. Additionally, Mr. Masood mentioned using planting palm trees in the arid areas would be another active biodrain. Also, the salinity problem would be reduced if more barley can be produced instead of wheat. Wheat and barley are used for the same reasons in Pakistan, but barley requires less time, less water, and is more salt tolerant. Another, technique the researcher mentions using animal manure, which increases nutrients through providing effective amounts of phosphorus. He mentioned using a year old or decomposed waste about five to ten tons of waste per one hectare. Adding anything above the given amount burns the crop. He mentioned using animal manure is a lot better than using commercial fertilizer because often times using commercial fertilizer degrades the land and contaminates the soil.

Researcher 2 (Muhammed Yaseen): A professor from the University of Punjab explained in details how salinity problems became more profound in Pakistan. Before the partition of India and Pakistan, the region was working under one irrigation network, but the seepage problem increase after the partition. Mr. Yaseen explained the problems were due to the Indus Water Treaty, which led towards building of canal networks that increased seepage problems. Thus, water losses from seepage became a major concern for the Pakistan's agriculture. SCARP wells were installed to reduce the waterlogging and salinity problem, which were semi-successful in the area. Even today, waterlogging and salinity issues are profound in Pakistan because water conveyance losses from canal seepage remain about 25 to 40 percent. Current, practices to avoid these problems involve applying gypsum, biodrainage system, flood-irrigation, and planting salt-tolerant crops. In addition, effective drainage practices such as using bed frown and ridge irrigation methods should be applied.

Mr. Yaseen's personal recommendations are planting salt tolerant crops and avoiding crop fixing in which farmers need to move away from planting one type of crops. For example, variety of rice can be grown in Pakistan that is salt tolerant; instead farmers stick to one type. Furthermore, gypsum can be used to reduce a buildup of salt if abundant amount of water is unavailable in the area. Mr. Yaseen did not recommend eucalyptus tress because the government of Pakistan is placing restrictions on them due environmental issues.

Sample Solution: These interviewers provide a perspective on effective salinity approaches that can be applied in Pakistan. To create an effective approach it is important to realize the common theme all interviewers stated. For example, all the interviewers agreed upon flood irrigation methodology being used in Pakistan to reduce salinity from the soil. Although flood irrigation is very popular in Pakistan, it will not be sustainable given Pakistan's declining water supply. Also, the local people indicated using biodrain and animal manure as ways to reduce salinity and provide nutrients to the soil.

The idea of developing biodrain is popular in Pakistan, but that is at a research level. The main concern is that many people are not aware of which biodrain would be the most effective for their area. The best approach would be to test different forms of biodrains in the FDP and MKPH SCARP region to develop the most effective biodrain for the area.

A sample solution would be to apply one of the methodologies stated from the older farms and study the soil salinity over time. The mechanism of using manure and rotten onion should be studied to provide accurate amount usage for the farmers. The methodology should be in the areas of Faisalabad and Sindh SCARP areas to enrich the damage soil. The expectation is that the nutrients provided from human waste and onions create a membrane that absorbs the salt from the ground. Most importantly, planting of palm tree should be studied in the area to see the impact on soil salinity. The palm tree like the eucalyptus can be grown in arid areas and be an effective biodrain. If the application is successful, the rural farms will find a resolution that is economical feasible and requires less water.

<u>Sample Design: (Figure 5)</u>

- Take 6 acres of farm land and sub divide the land
- During the winter season, add 1500 kg grams of animal manure and 500kg onion and corn product to one side
- Plant Eucalyptus tree and palm tree on the sides. Soil salinity will be measured during the growth period of the trees and see which one is the most effective.
- Towards end of the winter season the ground should be enriched with nutrients and have less salt
- If the application were successful, less water would be applied. Thus, water usage needs to be measured before and after.

Palm Tree	Palm Tree	Palm Tree	Palm Tree
Control	Animal and Human Waste with rotten onions	Control	Animal and Human Waste with corn
Palm Tree	Palm Tree	Palm Tree	Palm Tree

Figure 5: Design salinity solution in rural farm in Pakistan

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Appendix I

Figure 2: Map of Horizontal subsurface installation in Pakistan source: Riztma 2007

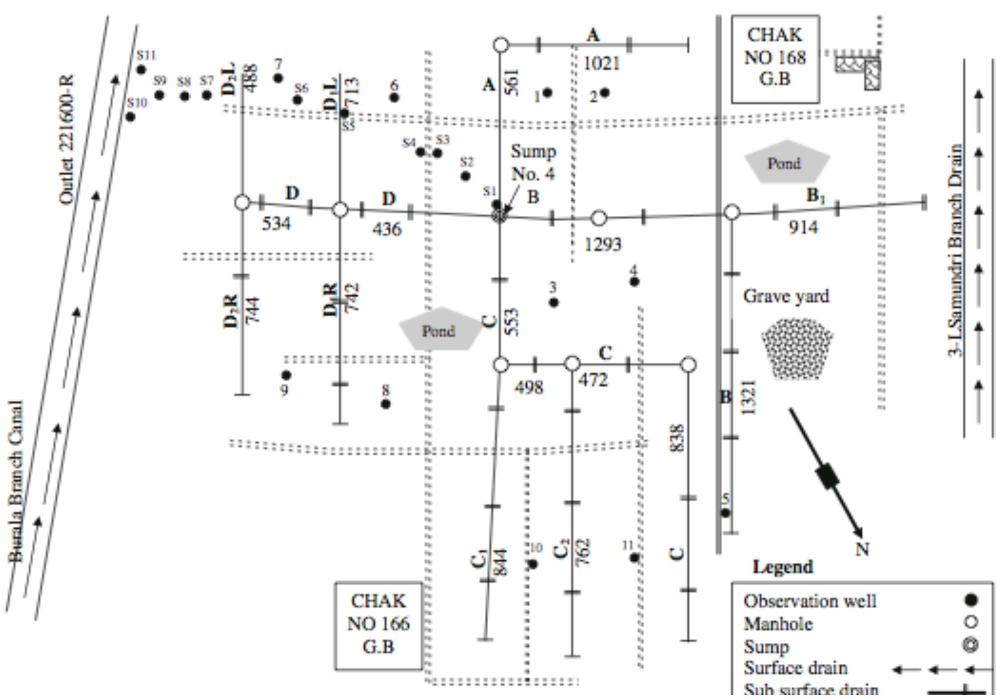

Figure 3: Design Layout of Fourth Drainage SCARP Well Source: Riztema 2007

Table 1: Salient feature of selected subsurface source: Azhar 2010

Description	Fourth Drainage Project	Mirpurkhas Tile Drainage
Gross Area(ha)	52,609	36,165
Subsurface Drainage Area(ha)	30,351	24,281 ha
Installation Period	1988-94	1994-1997
Design WT Depth (cm)	122	122
Type of System	Pumped	Pumped