Publication No: 146-2010

Impact Evaluation of Water Resources Development and Soil Conservation Activities in Pothwar

Pakistan Council of Research in Water Resources
Islamabad

Publication No.146-2010

Impact Evaluation of Water Resources Development and Soil Conservation Activities in Pothwar

Pakistan Council of Research in Water Resources
Ministry of Science and Technology

June 2010

© PCRWR 2010
Khyaban-e-Johar, H-8/1, Islamabad – Pakistan
Email: pcrwr@isb.comsats.net.pk

ISBN 978-969-8469-36-8

CHAPTER 1

INTRODUCTION

1.1 Introduction

The importance of water is increasing in most parts of arid and semi-arid regions in the world. Pakistan once a water surplus country is now facing serious shortage of water almost in all sectors. The country passed through one of the worst drought of its history extended over a period of 1997-2000. The population has grown from 47 million since independence to current 160 million. The per capita water availability therefore, has decreased very rapidly (presently about 1050 m^3) and soon the country will be one of the water deficit countries in the world (Kahlown and Majeed, 2004). Pakistan is basically an agricultural country with total area of 796,100 square kilometers (km^2), out of which about 221,100 km^2 are cultivated and 90,800 km^2 are culturable waste (MINFAL, 2006). About 25% of the cultivated area is rainfed and depends on rainfall for crop production. Rainfed areas are concentrated in Pothwar Plateau, northern mountains and northeastern plains of the country forming the largest contiguous block of dry-land farming in Pakistan. Pothwar region lies between the Indus and Jhelum rivers having a total area of 22,000 km^2, out of which about 10,000 km^2 is cultivated. The land resources of the Pothwar are characterized with fragmented land holdings. Its topography is undulating and the altitude varies from 300 to 600 m above mean sea level (Bhutta, 1999).

The main source of irrigation in Pothwar is rainfall and hence agriculture mainly depends upon rainfall. The rainfall occurrence in these areas is erratic with high spatial and temporal variation, and great difficulties arise in raising crops/plants due to uncertain water supplies (Sheikh *et al*., 1988; Shafiq *et al*., 1996). The annual precipitation ranges from 1800 mm in the Northeast to 250 mm in the Southwest and about 70% rainfall occurs during the monsoon season (WAPDA, 1982). Two major streams, Soan and Haro, carrying much of the areal runoff pass through the region and finally joins the Indus River, however Kanshi River transverses the

region. The total runoff potential of Pothwar Plateau is about 4320 million cubic meter (MCM) or 3.50 million acre feet – MAF (Bhutta, 1999).

In order to harvest rainwater in barani areas, initial studies were carried out by WAPDA in early 70 (ACE, 1963). Since then several water resources development activities such as construction of small dams, mini dams, ponds, soil and water conservation structures, etc. have been carried out by public and private sectors. Small Dams Organization (SDO) constructed 42 dams in Pothwar since 1961 (Bhutta, 1999; SDO, 2006). The potential of these dams however has not been fully exploited (NESPAK, 1991). Similarly, micro water resources have also been developed in the area by On Farm Water Management (OFWM) and Soil Conservation Department (Ashraf *et al*., 1999). In addition to crop production, this water is also being used for domestic and livestock purposes. All the small dams however, could only harvest 152 MCM (0.123 MAF) until 2006 in the region (Sheikh *et al*., 2007) out of total potential of 4320 MCM or 3.50 MAF (Bhutta, 1999). Therefore, a large amount of water about 4168 MCM (about 3.377 MAF) is being lost as surface runoff annually.

Thus to meet the growing water demand and possible future droughts, there is an urgent need to fully exploit the potential of available surface and groundwater resources. For this, it is necessary to evaluate the impacts of already implemented schemes and water resources development activities in the Pothwar region not only to assess their contribution but also help plan future activities for sustainable land and water resources management in rainfed areas. The major components of the study include:

- Compile information on the schemes completed by various agencies since 1980 on water storage, water conservation, groundwater development, improvement in water conservation & application efficiencies, groundwater levels, soil erosion, soil fertility, crop yield, cropping intensity, cropping pattern.
- Collect data on completed activities/studies undertaken through these schemes for impact assessment of water resources development.

- Number and type of water resources developed (open wells, tubewells, reservoirs) along with storage capacity/discharge in each tehsil of Pothwar (covering Chakwal, Rawalpindi, Attock, Jhelum Districts and Khushab Tehsil).
- Collection of hydrological and watershed characteristics data from 06 watersheds (Soan, Haro, Kanshi, Kahan, Rashi and Bunha Basins) such as rainfall, temperature, evaporation, wind velocity, infiltration rate, vegetation cover, topographic features, and to assess annual available precipitation and runoff and net water availability potential for future development through rainwater harvesting in Pothwar region.
- Collection of data from 6 small dams: 2 small in size, 2 medium and 2 large (out of 42 small dams), similarly 30 mini dams (out of about 600), 50 dug wells (out of about 5500), 30 lift schemes (out of about 4000), 30 portable sprinkler system (out of about 400) and 20 drip schemes (out of 140), covering effect of these activities on water use efficiencies, cropping pattern and crop intensity; livestock; and farm income. The data collection may be made from representative parts of Pothwar region giving reasonable coverage.
- Preparation of study report with recommendations on water and land resources development and management for increasing agriculture productivity in barani areas.

CHAPTER 2

METHODOLOGY

2.1 Description of Study Area

2.1.1 Location

The Pothwar Plateau lies between Indus and Jhelum Rivers at Longitude 71^{o} 40' to 73^{o} 38' and Latitude 32^{o} to 34^{o} (Figure 2.1) with total area of 22,000 square kilometers (km^{2}) including Salt Range expanding over five districts: Rawalpindi, Chakwal, Attock, Jhelum and Khushab. If Salt Range is excluded then all of the Attock district, Rawalpindi district except the Murree hills, about 75% of Chakwal district, and 15% of Jhelum district are included. This area is bounded by the salt range to the south and the Himalayas to the east. The relief is gently undulating plain with deeply incised river valleys. Elevation ranges from about 215 meters (m) along the Indus River to about 915 m in the hills north of Islamabad.

2.1.2 Climate

The rainfall varies across the area from 250 mm in the drier west to more than 1500 mm in the more humid eastern region. The climate also varies over the region with severe to mild winters and hot to mild summers. The temperature ranges from 25 ^{o}C to 45 ^{o}C in summer to below freezing to 20 ^{o}C in winter.

2.1.3 Hydrology

The Plateau is dissected by a series of streams that flow east to west – Haro, Reshi and Soan and southeasterly – Kanshi, Bunha and Kahan. The Indus river borders the north and west and, the Jhelum river flows below the ridge to the east (Figure 2.2). Three rivers of the area – Haro, Soan and Kanshi – yield most of the surface water.

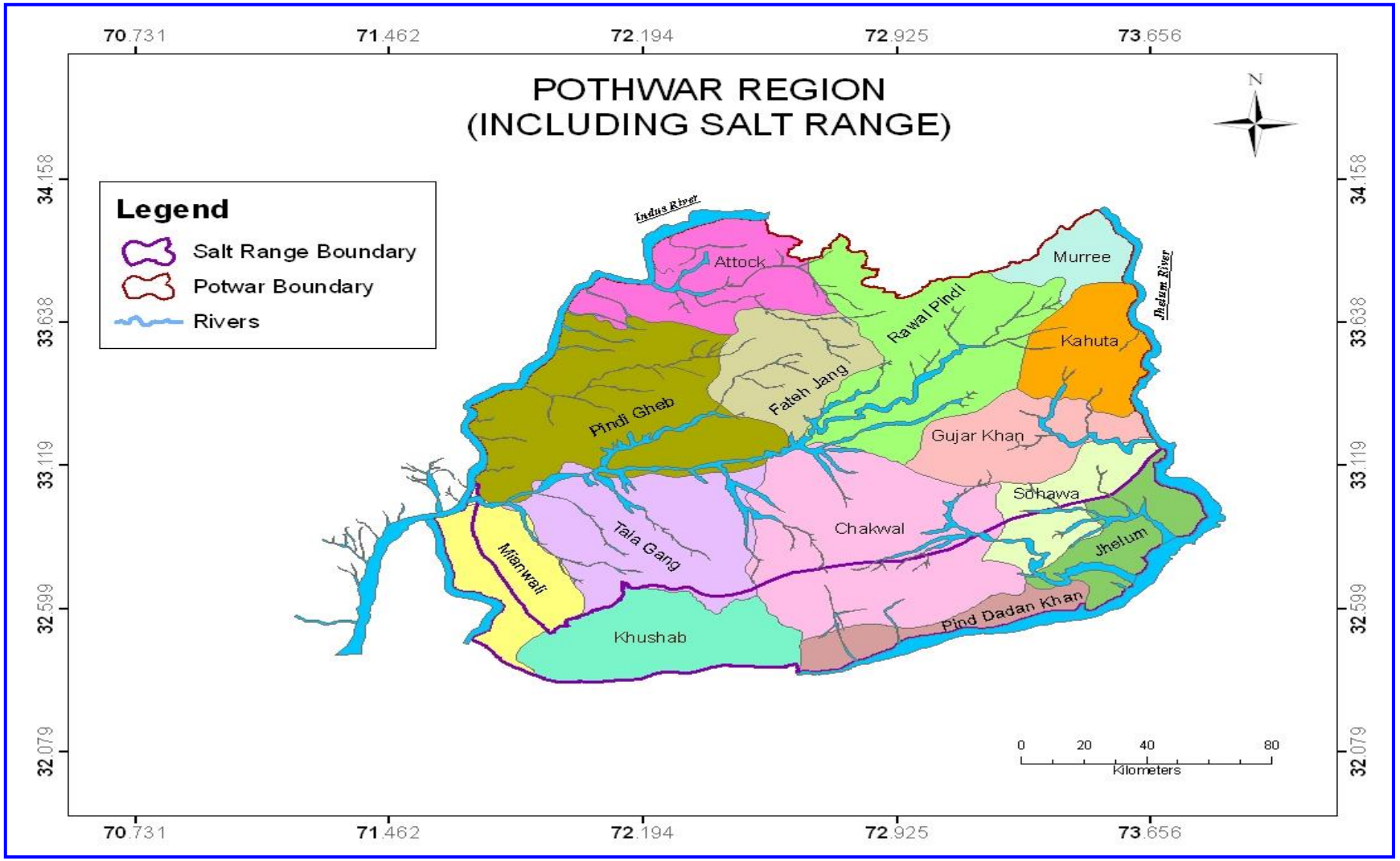

Figure 2.1: *Map of Pothwar Plateau (including Salt Range)*

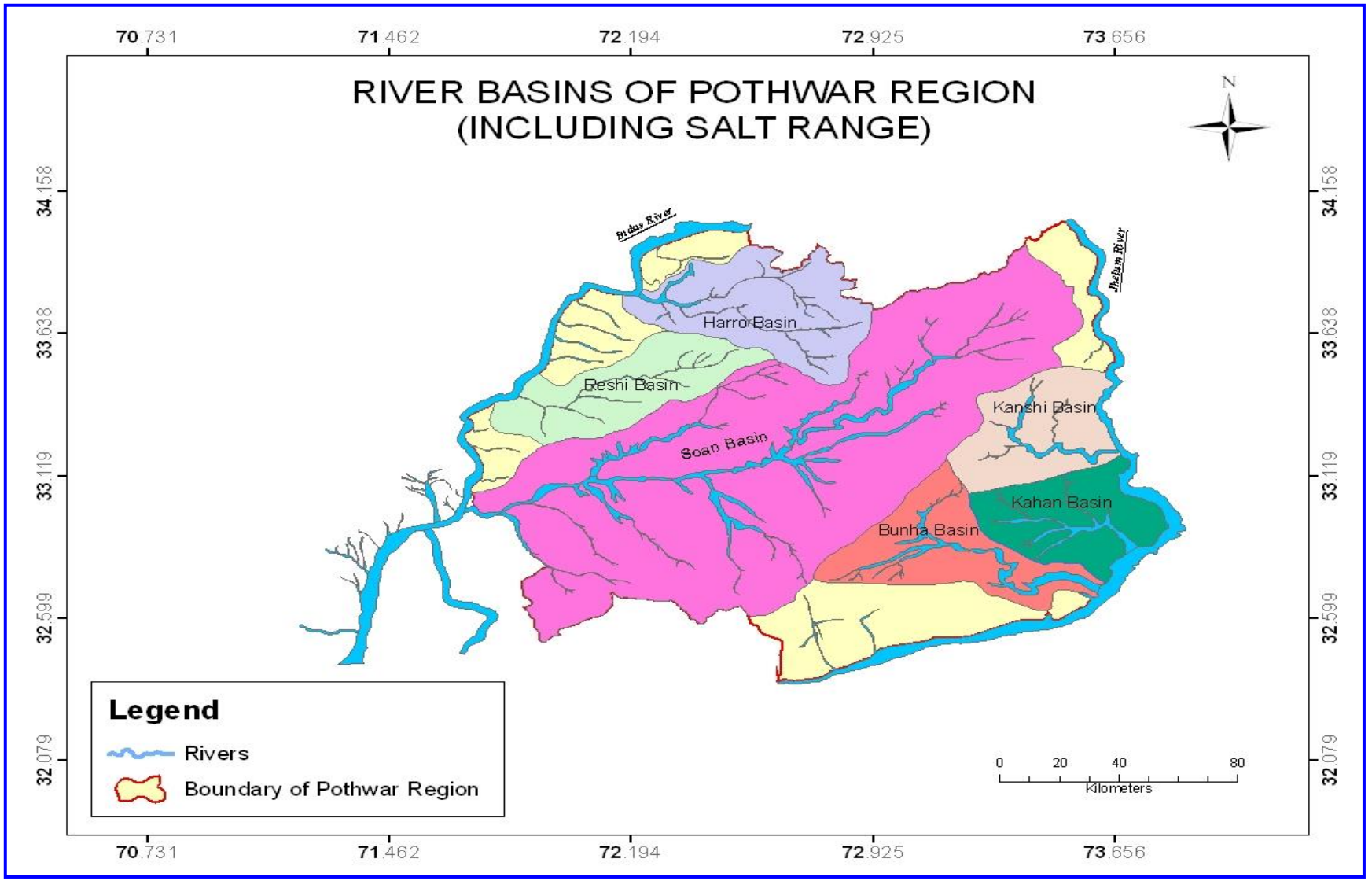

Figure 2.2: *River Basins of Pothwar Plateau (including Salt Range)*

Groundwater of the region is not available in copious quantity except at a few restricted locations. There are two important aquifers on the plateau. One of sand and gravel is limited in extent but is important for tubewells development in the areas of Rawalpindi, Islamabad, Hasan Abdal, the Chach Plain, the Upper Sil River (Fateh Jang), along Wadal Kas and near the ridge between the Soan and Kanshi rivers. The tubewells may yield 0.014 to 0.028 m^3/sec (cumecs) or 0.5 to 1.0 ft^3/sec (cusecs) of water. The second aquifer is sandstone having low transmissivity and it is most suitable for dug wells that can be pumped by small centrifugal pumps with yield of 190 to 380 litres per minute (lpm) and the quality of water is generally good for irrigation. The TDS (total dissolved salts) range from 300 to 800 ppm.

2.1.4 Land Use and Soils

The plateau is expanded over a total area of 22,000 km^2, out of which about 18,200 km^2 is without salt range. Erosion is widespread in the area particularly on the areas of loess soils. About 60% of the Pothwar land surface has eroded into gullies; the rest is gently sloping. Most of the gully formation is the result of geologic erosion, although the process has been controlled by various erosion control activities in the region. The land use in different parts of the region is given in Table 2.1. The cultivated area is the relatively maximum in Attock District followed by Chakwal and Rawalpindi Districts.

The land resources of the Pothwar are characterized with fragmented land holdings. Most of the agricultural soils have developed from materials transported by wind and water - loess, old alluvial deposits, mountain outwash, and recent stream valley deposits. Some soils have been formed in situ from the underlying rocks, which consist mainly of shale and sandstone. The soils are predominantly of medium texture, with a high proportion of clayey soils. Most of the soils are deep except for those developed in situ. Twenty six soil associations, nine complexes, and one undifferentiated group are recognized in the zone. The largest single unit is the Rajar complex, which occurs in dissected loess plains and is described as silt loams with no structure constituting about 8% of the area. Other significant units are the Balkassar association and complex developed in weathered rock plains and in ridge

and trough uplands. These constitute a total of about 10%. About 5% of the area has Guliana and Missa associations from loess plains. There are miscellaneous zones that constitute 50% of the area. Such areas are rough broken lands, rough mountainous land, gully land, hilly gravelly land, river beds and urban land.

Table 2.1: *Land Use Features of Area*

Tehsil	Reported Area (km^2)	Total Cultivated Area (km^2)	Uncultivated (km^2)	Culturbale Waste (km^2)	Forest (km^2)	Not available for Cultivation (km^2)
Rawalpindi District:						
Rawalpindi	1729	966	763	186	65	512
Taxila	304	165	140	13	20	107
Kahuta (including Kallar Seydan)	1100	435	666	81	417	167
Kotli Sattian	224	78	146	42	0	105
Gujar Khan	1475	931	544	91	24	429
Murree	390	120	270	24	102	144
Attock District:						
Fateh Jang	1453	693	760	102	107	551
Attock	1204	571	633	41	256	335
Pindi Gheb	1589	740	849	103	75	672
Jand	2316	976	1340	97	282	961
Hasan Abdal	358	212	146	19	9	118
Chakwal District:						
Chakwal	3177	1541	1636	141	248	1247
Talagang	2996	1529	1466	187	147	1132
Kalar Kahar	1027	284	744	42	230	471
Choa Seydan Shah	517	112	406	0	205	201
Jhelum District (only Barani Areas):						
Sohawa	1148	361	787	110	223	454
Jhelum	1153	437	716	143	134	439
Pind Dadan Khan	1176	485	691	354	90	246
Khushab District (only Barani Areas):						
Khushab	4104	2460	1644	270	405	970

Source: Bureau of Statistics, Statistics Division.

2.1.5 Agriculture

Agriculture is the main economy of the inhabitants of the area. More than 70% population lives in the rural areas and mainly depends upon agriculture. The principal crops of the area are wheat, maize, bajra, barley, pulses, groundnut, fruits and vegetables. The land of the area is fertile however varied topography with high spatial and temporal variability of rainfall is the major limiting factors in the development of agriculture of the area and so the socio-economic development. The contribution of rainfed areas is only 10% of the total food production in the country. The primary need of these areas is to increase the agriculture production which in turn requires water. Therefore, the development of water resources in these areas is essential.

2.2 Data Collection on Water Resources

In order to provide water for various uses, there have developed several water sources both at macro and micro levels. Small Dams Organization developed 42 several small dams in the area till 2006 mainly for agricultural purpose and limited drinking water supplies. Similarly, Soil Conservation Department, On Farm Water Management individually and with the help of Agency for Barani Areas Development (ABAD) developed mini dams, ponds and dugwells to supplement the rainfed agriculture. Similarly, to conserve the agricultural lands from erosion, Soil Conservation Department carried out several programmes including the activities like water disposal structures, outlets, retaining walls, G.I. spurs and plantation of local tress to control erosion. On Farm Water Management introduced high efficiency irrigation systems to utilize the available water more efficiently and enhancing crop production. These activities included sprinkler and trickle irrigation systems, lift irrigation, deep turbines and water conveyance structures. All the data on water resources developed in the area were collected from respective organizations and agencies.

2.3 Climatic, Hydrological and Physiographic Data

In order to assess the water resources potential of Pothwar Plateau, it was required to assimilate all the climatic, hydrological and physiographic data for the application of appropriate rainfall-runoff estimation tools. The data mainly included the rainfall, temperature, discharge and other climatic parameters if available. The data in this regard have been collected from several sources including Water and Power Development Authority (WAPDA), Punjab Irrigation and Power Department (I&P), National Agricultural Research Centre (NARC) Islamabad, Soil and Water Conservation Research Institute (SAWCRI) Chakwal, and Pakistan Meteorological Department (PMD).

2.4 Participatory Appraisal Survey

For the impact evaluation of developed water resources activities in the area, it was planned to collect data directly from the beneficiaries. For each water resources activity, a separate questionnaire was designed and as such eight questionnaires were developed. The major focus of the information collected through these questionnaires was to assess the role of the developed activities to enhance the agriculture productivity and so the farm income. These questionnaires were tested in the field and necessary amendments made before undertaking participatory appraisal survey from the study area. The questionnaires developed are given in Annexure-I.

2.5 Data Processing and Analysis

All the collected data, information, outcome of assessment survey and past impact studies were reviewed, processed and analyzed to evaluate the impacts of developed activities with the standpoint of role of water availability particularly for agriculture development and productivity. The outcome of the study would guide in the formulation of future programmes for land and water development in the area.

CHAPTER 3

WATER RESOURCES DEVELOPMENT SCHEMES

3.1 General

Water resources development calls for large-scale water initiatives to develop the full potential of the natural resource base into a well-planned and well-managed irrigation systems comprising of storage dams, water-conveyance structures, tubewell schemes, flood control activities, drainage facilities and a regulation mechanism. For the development of agriculture in rainfed areas, there are opportunities for small initiatives to utilize surface water or groundwater flows. These include dugwells; small capacity tubewells; lift pumps operating from streams and mini dams; and soil conservation structures to prevent the erosion and to increase the moisture retention capacity of agricultural lands.

The importance of using available water resources for developing agricultural sector in rainfed areas was recognized in early years after the emergence of Pakistan (Khan *et al*., 1988). However, the “high” cost of developing barani water resources has been often cited as a main reason not to pursue existing opportunities. Whereas the cost comparison between rainfed and main canal irrigation system are rarely complete, leaving less support of policy makers for the commitment of public funds. In fact, several factors are ignored during the comparison of rainfed and irrigated areas water resources development costs. Firstly, the cost of storing water is rarely included in the main canal system otherwise the total investment is too high. Secondly additional cost is required for drainage in irrigation canal system whereas no drainage is needed in rainfed areas like Pothwar due to sufficient land gradient. Thirdly, the water requirements in rainfed areas are significantly different than in Indus Plain where no agriculture is possible without irrigation. Fourth the irrigation does more than increasing cropping intensity in rainfed areas - it changes from a partial contribution toward total family income to a full-time occupation and continuous on-farm employment. Such effects are difficult to quantify but knowing the water will be available, greatly increases the cropping intensity, the rate of

adoption of new agricultural technology and the returns on the investment in irrigation facilities.

With the same objectives, several water resources development schemes were implemented in the region from time to time and by various development and research agencies in the region. Brief description of surface and groundwater development, soil conservation and agriculture extension schemes alongwith data on activities implemented are being presented. Further, the role of relevant research organization in these developments has also been discussed. This would help understand the nature and extent of water resources development taken place in the area.

3.2 Surface Water Development Schemes

Rainfall is the major source of water supply in the area enabling water supply for all uses. The rainwater is used either directly from streams/rivers or stored in small or medium size reservoirs for later use. The hydrology of the area is described by three major rivers (Soan, Haro and Kanshi) and several small streams/Creeks carrying mostly rainwater and partial spring/return flow. The investigations for construction of water storages for this area were first started in 1954 by the Punjab Irrigation Department. However, the work remained restricted to only preliminary surveys. During 60s, a Small Dams Organization was set up under the control of Provincial Governor. Later it was brought under the control of Provincial Irrigation and Power Department (P&I), now Punjab Irrigation and Drainage Authority (PIDA). The topography of the area is such that no large dam can be constructed. Therefore, the macro water resources development ascribes mostly small and medium storage reservoirs for multiple users/beneficiaries. Whereas on-farm reservoirs benefiting one or few farmers namely mini dams and ponds are covered under micro water resources development schemes under the purview of Punjab Agriculture Department directly or through Agency for Barani Areas Development (ABAD).

3.2.1 Macro Water Resources Development

Macro Water Resources development attributes to the extent of activities in terms of storage, supplies, areal coverage and number of beneficiaries/farmers. Some preliminary surveys during 60s identified significant number of sites suitable for construction of small dams in the area.

The first small dam namely *Rawal Dam* was completed in 1962. The major part of its storage was dedicated for water supply to Rawalpindi city and very small portion for agriculture. After this, 18 small dams were constructed until the launch of a mega project in 1986 by the Government of Punjab with the assistance of Asian Development Bank (ADB). Under this project, 12 new dams were constructed besides rehabilitation and command area development of 09 old dams spreading over a period of 1986 to 1994 with total cost of Rs 895.58 million (20% Foreign Funding). After this, another project was launched by Small Dams Organization to construct more small dams. At present, there have been completed 42 small dams in the area with the main focus for agriculture development and partly for drinking water supply. All these dams have total water storage capacity of 123 MCM. The characteristics of these dams are given in Table 3.1 and location map is shown in Figure 3.1. Although these developments helped bring existing rainfed and new lands under irrigated agriculture but most of the agriculture is still practiced on traditional methods and dependent on rainfall as the developed storage facilities are not being utilized to their full potential due to various management and lack of extension services. The impact evaluation of these activities is presented in coming Section 3.8 as well as in Chapter 5.

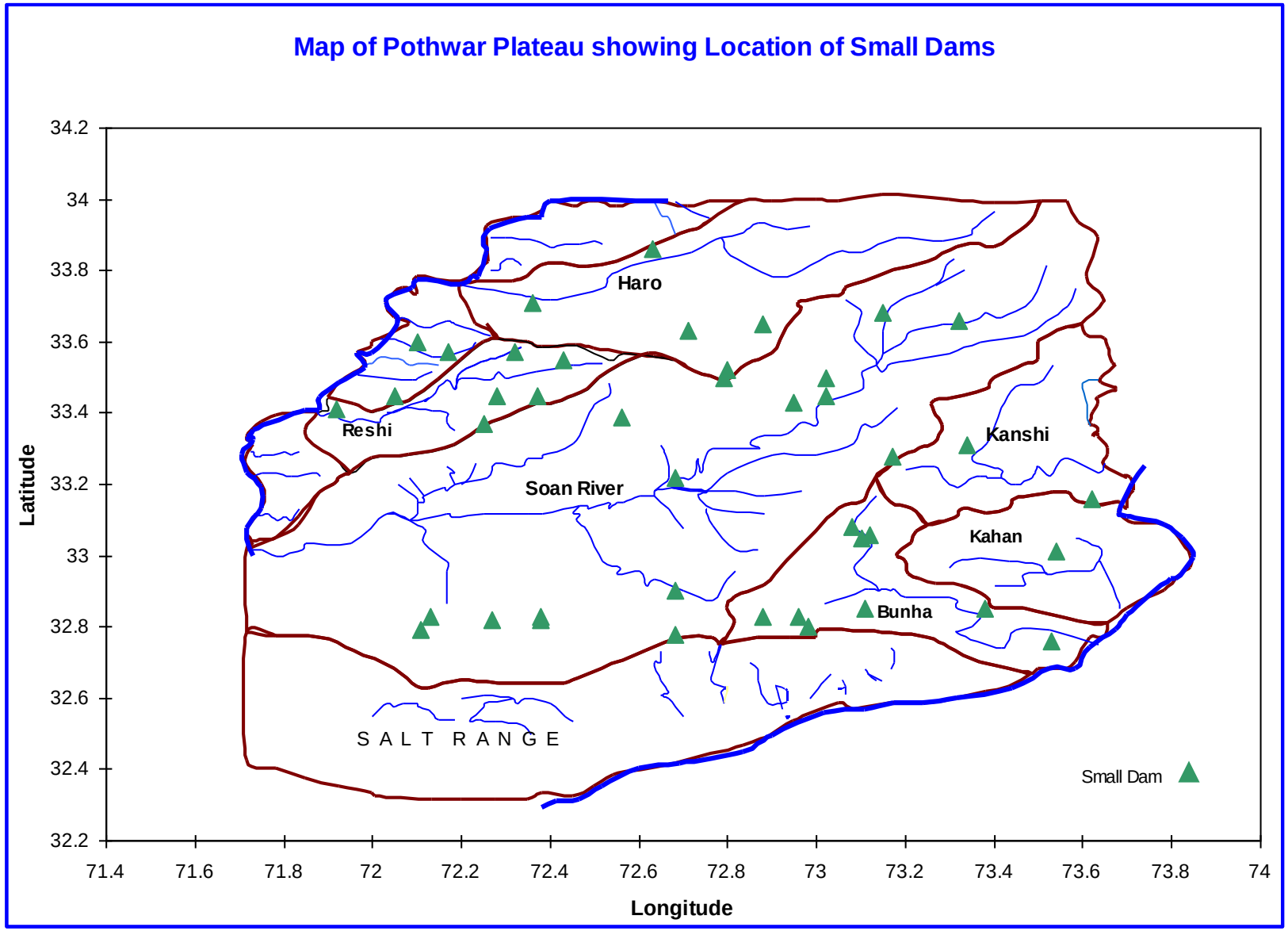

Figure 3.1: *Small Dams Constructed in Pothwar*

Table 3.1: *Small Dams Constructed in Pothwar*

S. #	Name of Dam	Longitude	Latitude	Location	C.C.A	Catchment Area (sq. miles)	Gross Storage Capacity (acre-ft)	Live Storage (acre-ft)	Completion Year
1	Rawal Dam	73.15	33.68	Islamabad	500	106.25	43915	43000	1962
2	Misriot	73.02	33.50	Rawalpindi	100	3.12	504	242	1963
3	Sipiala	72.79	33.50	Attock	140	4.02	565	267	1964
4	Bango	72.80	33.52	Attock	-	-	-		-
5	Ratti Kassi	72.43	33.55	Attock	650	-	2116	1012	1970
6	Nirali	73.08	33.08	Rawalpindi	250	8.5	754	416	1970
7	Dungi	73.34	33.31	Rawalpindi	350	3.55	1760	960	1971
8	Dhok Tahlian	72.98	32.80	Ckakwal	-	7.7	-		-
9	Kanjoor	72.56	33.39	Attock	2000	12.44	2627	2400	1978
10	Cjammo BPR			Attock	1500	9.5		1173	1979
11	Gurabh	72.38	32.83	Ckakwal	350	6.5	972	679	1966
12	Dhurnal	72.11	32.79	Ckakwal	650	8.11	1570	791	1971
13	Qibla Bandi	72.63	33.88	Attock	850	9.13	3650	1128	1971
14	Khokher Zer	72.88	32.83	Ckakwal	800	8	3312	2602	1979
15	Garat	73.54	33.01	Jhelum	1600	5.41	2228	1690	1982
16	Walana	72.68	32.90	Ckakwal	1200	10	2193	1278	1984
17	Siraj			Ckakwal	1800	6	-	1555	1985
18	Khasala	73.02	33.45	Rawalpindi	1250	9.8	2415	1498	1985
19	Shah Pur	72.71	33.63	Attock	4308	78.74	14320	4079	1986
Under Small Dams Project in Punjab (1986-96)									
20	D. Sanday Mar	72.88	33.65	Rawalpindi	650	3.55	862	518	1990
21	Bhugtal	72.27	32.82	Ckakwal	600	8.75	1140	673	1990
22	Nikka	72.68	32.78	Ckakwal	692	11.12	1243	827	1990
23	Mirwal	72.37	33.45	Attock	1050	14.5	3765	2726	1990
24	Jabbi	72.28	33.45	Attock	1495	13.63	3079	2753	1991
25	D. Qutab Din	73.11	32.85	Chakwal	711	5.9	1976	827	1991
26	Kot Raja	72.96	32.83	Chakwal	1112	9.34	2844	1344	1991
27	Jammargal	73.53	32.76	Jhelum	660	5.86	2432	1173	1992
28	Jawa	72.95	33.43	Rawalpindi	800	3.61	1575	900	1994
29	Sjakardara	72.36	33.71	Attock	4200	60.58	5711	2082	1994
30	Tainpura I	73.12	33.06	Jhelum	3410	16.42	5641	3858	1994
31	Tainpura II	73.10	33.05	Jhelum			3395		
32	Pira Fatehal	72.38	32.82	Chakwal	1366	26.53	7400	2900	1995
Dams Constructed by Small Dams Organization under Federal and Provincial Funds									
33	Basal Dam	72.32	33.57	Attock	500	-	1700	1020	2004
34	Mial Dam	72.13	32.83	Chakwal	935	-	3200	1920	2004
35	Lehri Dam	73.62	33.16	Jhelum	2220	-	5705	3423	????
36	Jamal Dam	73.17	33.28	Rawalpindi	1488	-	1860	1116	2006
37	Salial Dam	73.38	32.85	Jhelum	450	-	527	316.2	2006

S. #	Name of Dam	Longitude	Latitude	Location	C.C.A	Catchment Area (sq. miles)	Gross Storage Capacity (acre-ft)	Live Storage (acre-ft)	Completion Year
38	Thatti Dam	72.25	33.37	Attock	300	-	600	360	2006
39	Sawal Dam	72.68	33.22	Attock	930	-	2400	1440	2006
40	Talikna Dam	72.17	33.57	Attock	1000	-	2050	1230	2006
41	Jabba dam	71.92	33.90	Attock	400	-	860	516	2006
42	Jalwal dam	72.05	33.45	Attock	2364	-	5000	3000	2006

Source: Punjab Small Dams Organization, Islamabad.

3.2.2 Micro Water Resources Development

On-farm water resources development activities benefiting one or few farmers ascribes macro water resources development. In rainfed areas of Pothwar, the land holdings are small relative to irrigated areas. The provision of irrigation supply to fragmented lands has been the main limiting factor for low agricultural productivity in the region. To handle the situation, concept of micro water resources development was introduced as the conservation/collection of runoff and its utilization is of paramount importance in this region. These areas in spite of significant economical potential remained relatively neglected in the past. After creation of ABAD in 1978 various multi-sectoral and integrated projects were implemented. During 1981 to 1990, Barani Area Development Project (BARANI-1) financed by IFAD (International Fund for Agriculture Development) was implemented in two tehsils, Shakargarh and Sohawa, out of which only Sohawa falls in Pothwar region. The success of this project gave rise to formulation of Second Barani Area Development Project (SBADP) co-financed by ADB and IFAD. This was also a multi-sectoral project with major focus on water resources development. The project was expanded over the period of 1992-98. After this, Barani Village Development Project (BVDP) was recently completed in six tehsils of Pothwar (Attock, Pindi Gheb, Talagang, Gujar Khan, Jand, P.D. Khan) from 1999-2007. There is plan for Phase-II of this project. During drought period of 2001-2004, funding was also provided under DERA (Drought Emergency Relief Assistance) Programme for development of micro water resources in the area. Apart from this, there has been a regular

Water Resources Development Scheme under limited non-development budget for construction of mini dams only. The activities developed in all districts of Pothwar (including Salt Range) are given in Table 3.2 until June 2007. The impact evaluation of these activities is presented in Chapter 5.

Table 3.2: *Micro Water Resources Developed in Pothwar (including Salt Range)*

S.No.	Project Name	Period	Mini Dams (Nos.)	Ponds (Nos.)
1	Soil Conservation in Mini dams on Sub-Catchment Basis	1978-86	98	91
2	First Barani Area development Project	1981-90	-	109
3	Second Barani Area Development Project	1990-98	323	693
4	Water Resources Development in Barani Areas of Punjab through Construction of Mini dams/ Ponds on Sub-Catchment Basis	1994-2000	88	163
5	Barani Village Development Project (BVDP)	1999-2007	366	292
6	Drought Emergency Recovery Assistance Project (DERA)	2001-2004	56	93
Total (Nos.)			931	1441

Source: ABAD and Directorate of Soil Conservation.

3.3 Groundwater Development Schemes

Groundwater is the only widely exploitable source of water in the area. The aquifers are not continuous and their potential is also limited. There have been conducted various hydro-geological investigation to explore groundwater in the area (e.g. WAPDA 1979; Khan *et al*., 1981; Khan and Ismail, 1982; Ismail, 1983). There are three fairly extensive areas and four areas of limited extent that could be exploited by tubewells. The principal areas are the Chach plain, Hasan Abdal-Taxila area, and the area around Rawalpindi and Islamabad. Smaller but significant are the tracts at Pindi Gheb, along the left bank of Soan River, along the Soan-Kanshi river topographic divide at Gujar Khan, and in smaller circular area at Talagang. There are in addition, extensive areas of sandstone aquifers that yield water from

dugwells, 30 m deep although the average depth is less than 15 m – in quantities adequate for domestic supply or to irrigate one to two acres.

In early 60s, the dugwells have been the main source of groundwater extraction in the area, driven manually or by old Persian wells (Figure 3.2). There have been about 5000 dugwells only in Soan Basin until 1980 (WAPDA, 1982). However, the development of pumping technology led to utilization of electric or diesel driven pumping systems to draw water from dug wells or shallow sources. The field information provided that most of the groundwater development activities in the past were done by the individuals to benefit certain cultivated land or for the community use. After the completion of hydro-geological investigation, most tubewells installation were carried out by public sector supplying water to urban areas for domestic and industrial use like Islamabad and Rawalpindi. At present, 170 tubewells in Islamabad whereas more than 200 in Rawalpindi are providing water to the community and industrial units.

Figure 3.2: *Modes of Groundwater Extraction*

The public sector also provided support to the farmers/users through various projects including SBADP, BVDP, funding under DERA Programme and other limited funding projects defined in Section 3.2 for construction of dugwells and tubewells, installation of turbines and lift pumps mainly for the development of agriculture. The total groundwater sources developed under these projects in various districts of Pothwar (including Salt Range) are given in Table 3.3.

Table 3.3: *Groundwater Sources Developed in Pothwar (including Salt Range)*

S.#.	District	Dugwells (Nos.)	Tubewells (Nos.)	Turbines (Nos.)	Lift Pumps (Nos.)
1	Rawalpindi	192	03	05	51
2	Attock	959	06	15	211
3	Chakwal	683	16	48	396
4	Jhelum	255	09	03	234
5	Khushab	74	32	22	87
Total		2163	66	93	979

Source: ABAD, Directorate of Soil Conservation and On-Farm Water Management.

3.4 Soil Conservation Schemes

Soil erosion is the removal of surface material. There are two major types of erosions: geological erosion and accelerated erosion. Geological erosion includes soil forming as well as soil eroding process, which maintains the soil in favorable balances, suitable for the growth of most plants. The accelerated erosion includes the deterioration and loss of soil as a result of man's activities. It is normally associated with changes in natural cover or soil conditions. The two main agents of erosion are wind and water, and accordingly the erosion is named as wind erosion or water erosion. The major variables affecting soil erosion are climate, soil, vegetation and topography.

The process of soil erosion involves soil detachment and transportation. Rain drop erosion is soil splash resulting from the impact of water dropping directly on soil particles whereas the sheet erosion is the next stage of soil erosion where the soil is uniformly removed in thin layers from sloping land. Next stage is rill erosion where the removal of soil by water is from small but well-defined channels or stream, when there is a concentration of overland flow. The gully erosion is an advanced stage of rill erosion and it is the most severe form of erosion (Anwar, 1986).

The Pothwar Plateau looks, in places, like a moon landscape, with its deep gully incisions. The process of gully erosion has been going on for 20,000 years, and it will continue naturally. What is not necessary is the man-made acceleration of the process from tilling or from grazing the land. This is the erosion that should be the target of development planners, to be included as an important component of all development projects in the barani tract. The main soil-conservation problems of the Pothwar are:

- Erosion of the top fertile soil in the cultivated area;
- Formation and deepening of gullies by run-off;
- Loss of surface run-off water to agricultural production;
- Poor management and conservation of rainwater;
- Ineffective and uneconomical use of gullied lands; and
- Siltation of water reservoirs and nullah beds.

In order to conserve the barani lands, erosion control activities were carried out initially by Forest Department and then in 70s by Punjab Soil Conservation Department in the region under non-development budget which has been very limited in the past. To boost up the process of erosion control and land development several projects were implemented including BARANI-1, SBADP and BVDP as defined in Section 3.2. Under these projects, the achievements made in the form of soil conservations works and stream bank training are given in Table 3.4 implemented in all districts of the region (including Salt range).

Table 3.4: *Soil Conservation Activities in Pothwar (including Salt Range)*

S.No.	District	Soil Conservations (acres)	Streambank Training (Kilometers)
1	Rawalpindi	240,765	364
2	Attock	158	287.50
3	Chakwal	104,492	376.25
4	Jhelum	86,124	204
5	Khushab	-	89
Total		431,539	1,320.75

Source: ABAD and Directorate of Soil Conservation.

3.5 High Efficiency Irrigation Systems

Water is a scarce source in study area as the occurrence of rainfall is erratic with high spatial and temporal variations. The conservation and optimum utilization of the rainfall is of paramount importance for land and water productivity. However, large tracts of agricultural land are still lying unproductive due to poor management of water and agronomic practices. The heavy reliance of crop production on rainfall sometimes result complete crop failure.

Each millimeter of water collected, stored, conserved and saved in these areas could increase yield of wheat by an average of about 10 kg/ha (Marshall and Holmes, 1988). In the barani areas, due to topographic conditions, surface irrigation schemes are not practicable. Farmers use obsolete methods of irrigation resulting poor application and distribution. Moreover, cost of pumped/exploited water is quite high and the available water is not only inadequate but also unreliable. Appropriate technologies must be used for the optimal utilization of the limited water resources available.

High efficiency irrigation systems such as sprinkler and trickle system could help fill the gap between water supply and demand, and achieve maximum production per unit of water. Though sprinkler/drip irrigation system has been adopted worldwide and million of hectares of deserts have been converted into green lands, and there also exists a large potential for its adaptation in the country, yet it could not get the required popularity.

The sprinkler and trickle irrigation systems were introduced in Pothwar by ABAD and On Farm Water Management under Second Barani Areas Development Project (SBADP). The purpose of installation of sprinkler system was to enhance yield of traditional crops (wheat) as well as to grow cash crops/ vegetables. The trickle system was introduced mainly for orchards. The total numbers of systems installed in the area are shown in Table 3.5.

Table 3.5: *Sprinkler and Trickle Systems Installed in Pothwar*

S.No.	District	Sprinkler Systems (No of Sites)	Trickle/Drip Systems (No. of Sites)
1	Rawalpindi	400	140
2	Attock		
3	Chakwal		
4	Jhelum	-	-
5	Khushab	-	-
Total		400	140

Source: ABAD, On Farm Water Management.

3.6 Irrigation Canal System

Initiatives for water resources development were driven by the relative locations and elevation of water and cultivable land. This relationship led to conceptualization of the high-level and low-level link canal systems in the region (NESPAK, 1988). These two linked systems were conceived with the development mode of connected reservoirs. The relative elevations of some 50 existing and proposed small dams were studied with topographic contours of the plateau and the location of lands with

irrigable soils. Of the more than 2,000 km^2 of irrigable lands identified, 1,500 km^2 lie within the boundaries of the proposed two link-canal systems.

The high-level system begins at Khanpur Dam on the Haro River. A tunnel and pressure conduit 5 kms long would carry water to a junction near Golra Village (elevation 570 m). The junction may irrigate four command systems (Chach Plain, Jandal/Central Basin Plain, Eastern Khaur Plain and Gujar Khan) and can also supply water to the Wah and Taxila Industrial complexes and municipal and industrial needs of Islamabad and Rawalpindi. The low-level link canal is also commanded by the existing left-bank canal from Khanpur Dam and by the Tarbela Reservoir (elevation 475 m). This would make possible to store wasted flood waters of the Indus River in the reservoirs of the Pothwar Plateau.

Although this proposed initiative was sufficient to meet most future water demands but was subject to more intensive investigations and investment involved. As a result, limited progress could be made on the subject by providing supply to Islamabad, Rawalpindi and some parts of Wah/ Taxila.

3.7 Role of Research Institutions in Pothwar

There are many research institutions in the region working with different mandate. The role and activities of various departments is described as follows.

3.7.1 Water Resources Research Institute (WRRI), NARC

Water Resources Research Institute (WRRI) is a department of National Agricultural Research Centre under Pakistan Agriculture Research Council (Federal Ministry of Food, Agriculture and Livestock). WRRI has been involved in water and agriculture related research in many parts of the country. For research on arid land and water resources issues in Pothwar, WRRI also established its field research sites at Fateh Jang (Attock) and Satra Mile (Islamabad).

3.7.2 Barani Agriculture Research Institute (BARI), Chakwal

Barani Agriculture Research Institute (BARI) was established in the region for research and demonstration of rainfed agriculture including: introduction of efficient

agricultural practices; research on high yield and drought resistant varieties; strengthening extension and farmers training services; etc. BARI has sufficient infrastructure along with large farm area to carry out research on related issues. BARI has been involved for undertaking research component of various agriculture based land and water management projects implemented in the area.

3.7.3 Soil and Water Conservation Research Institute (SAWCRI), Chakwal

Soil and Water Conservation Research Institute (SAWCRI) was established with mandate to carry out research on soil conservation and rainwater harvesting in the area. SAWCRI performs its research activities at its research farm as well as on farmers' land. SAWCRI has also undertaken various projects in collaboration with ABAD and Soil Conservation Department on several soil and water conservations issues.

3.7.4 Water Resources Research Centre (WRRC), PCRWR

Water Resources Research Centre (WRRC) is one of field research centres of Pakistan Council of Research in Water Resources (PCRWR) based at Headquarter Islamabad. Under the mandate of PCRWR, this centre is responsible for carrying out research, dissemination and assessment studies on land and water resources management for agriculture development in barani areas. Several research and demonstration projects are being implemented in the area with major focus on integrated land and water management for agriculture development leading socio-economic uplift.

3.8 Evaluation Studies of Developed Activities

Besides undertaking various water resources development and management, the concerns also arose to assess the impacts of numerous implemented projects in the Pothwar tract. This was vital to evaluate contribution of water sector development projects in barani agriculture and resultant impacts on socio-economic conditions of the area. Various impact assessment studies have been carried out in the study area. A brief review of those studies is presented as follows.

Shah (1984) evaluated small dams in Punjab and found that due to the availability of water, the crop yield has been increased 36% in case of wheat and 51% in case of maize. However, the programme was not successful in term of economics, as the benefit-cost ratio was less than 1. They attributed this to the technical, socio-economic, institutional problems and lack of agricultural support services. Khan *et al*. (1988) evaluated 22 small dams in Punjab and found that average cropping intensity was 110% and average land use intensity was 92.3%. He suggested that formal and informal organizations of the farmers could play a significant role in the effective utilization of the water, proper construction, rehabilitation, operation and maintenance of watercourses.

NESPAK (1991) during the assessment of small dams reported that the achieved cropping intensities were very low compared to the set targets. These ranged from 22 to 29% at dams in Punjab against an average target of 84%, whereas in NWFP, it ranged from 33 to 39% against a target of 81%. Iqbal and Shahid (1992) concluded that less than one third of the proposed area was being irrigated by small dams. The desired changes in cropping pattern could not be accomplished. They suggested weekly rotational schedule/warabandi in which equitable and reliable distribution of water could be made possible to every farmer located at different reaches of water channels. An enlightened and imaginative extension service was required to motivate farmers to bring about desired changes in cropping pattern and adopt recommended practices. Azhar (1995) attributed low land and water productivity to the lack of knowledge about irrigation scheduling in the command areas. It was reported that 75% of the farmers apply less water than the crop water requirements, two third of farmers apply first irrigation very late.

Shahid *et al*. (1996) reported that the SDO has been quite successful in achieving construction related physical targets of the small dams' project. However, follow up activities after dams construction have been weak. After dam construction, efforts should be made to bring culturable command area under irrigation, which ultimately could contribute towards better quality of life and living standards of rural community. They considered a slight shift in cropping pattern towards the high value crops including rabi fodder, rabi and kharif vegetables as a positive contribution of

Small Dams Project at both newly built and rehabilitated small dams. Cheema and Bandaragoda (1997) conducted base line survey for farmers organizations of Mirwal and Shahpur dams. They reported that the cropping and land use intensities were 123.4 and 63.5% under the irrigated area of Mirwal dam, respectively whereas these were 117.7 and 90% at Shahpur dam, respectively. Iqbal (1989) reported cropping intensity of 121.3% in the irrigated area of Shahpur dam.

Bhatti *et al*. (1999) pointed out that the distribution of water in the command areas due to poorly maintained watercourses were deficient. The level of the serving channels was frequently below the elevation of command area fields. Furthermore, farmers had operated the irrigation systems without an allocation and distribution schedules. As a consequence, substantial amounts of irrigation water were wasted and the distribution and application of water were inequitable and inefficient. Bhutta (1999) suggested that to fully exploit the benefits of additional investment made at small dams in the form of improved irrigation network, not only the share of high value crops in the cropping pattern should be improved, but some non-traditional crops may also be introduced. IIMI (1999) reported that the small dams system offered a precious opportunity for the sincere promotion of reforms in the irrigation sector. They were independent of the large scale Indus Basin Irrigation System and therefore, more easily manageable by smaller units of water users organizations and support service personnel.

Khan *et al*. (1999) carried out evaluation of second barani area development project. This is one of the major projects implemented in area. The results revealed that the project targets were more than 95%, the cultivated area of beneficiaries increased by 28.2 percent. The major contribution was from integrated soil conservation, agriculture engineering and On Farm Water Management activities. The land use intensity increased by 15 percent. Due to construction of mini dams and ponds, significant change in cropping pattern was also observed. Ashfaq *et al*. (2003) reviewed the issues and options for integrated land and water resources management in Pothwar region. The study identified various limitations including traditional irrigation and agronomic practices, poor land management and limited storage facilities to harvest the rainwater causing low productivity. However, the

integrated management of available land and water resources would help enhance the agriculture development as well sustainability of the available resources in the region.

Ashraf *et al*. (2007) conducted a study to document the existing status of agricultural practices and their impacts on the socio-economic conditions of the farmers of three small dams namely: Jawa, Khasala and Dhok Sunday Mar. Seepage from these dams has built the groundwater resource. The installation of dugwells has increased many folds after the construction of these dams. The land use and crop intensities and crop yield have also increased many folds. Transformation of cropping pattern from traditional to high value crops has taken place. An analysis of inflow-outflow from the dams' reservoirs shows that releases are not meeting the designed water requirements resulting less increase in intensity than the planned value. However, if properly managed, more area could be irrigated with existing facilities and available water resources. Nevertheless, there are several bottlenecks in the full utilization of these small dams. These include: (i) illegal water diversion, (ii) non-functional water user associations, (iii) poor maintenance of watercourses, (iv) tempered outlets (moghas), (v) poorly maintained field channels, (vi) lack of agricultural support services etc. Well coordinated efforts by Small Dams Organization (SDO), Agriculture Extension and On Farm Water Management (OFWM) Departments could help overcome these issues. In conclusion, the study proposed strategies for efficient management of available water resources.

These studies show that the potential of water resources development and management in barani areas may contribute significantly in agriculture growth as well as socio-economic uplift of these areas. However, there are some lacking in the identification of projects and site specific implementation, planning and maintenance of developed activities, and importantly in-effective and/or under utilization of available resources maintaining their sustainability.

CHAPTER 4

RAINFALL-RUNOFF POTENTIAL IN POTHWAR

4.1 General

The rainfall-runoff analysis from an area involves the estimation of runoff generated due to incidental rainfall under certain land use and soil-moisture conditions. The potential runoff from Pothwar region is required to be estimated which would help planning for further water resources development and management in the area.

The rainfall-runoff transformation may assume a wide variety of forms, ranging from the linear method to multi-parameter non-linear models of catchment behaviour. The selection of a method varies with the catchment and the problem to be analyzed as well as the availability of necessary record. In the present case, the estimation of average total runoff due to rainfall on annual and/or monthly basis is required which is equivalent to the excess rainfall. The total runoff is the difference of total precipitation and total hydrological losses. The losses are of various kinds including: interception, evapotranspiration, depression storage and infiltration, and vary depending upon the prevailing conditions and nature of a catchment such as rural, urban and/or forest (Mutreja, 1990). The schematic diagram representing these losses is shown in Figure 4.1.

During a single major storm capable of producing runoff, evapotranspiration losses are negligible and the losses by interception and depression storage are generally small as compared to infiltration. The first shower is sufficient to fill up the storage quantities involved in interception by vegetation and in local depressions. Infiltration however continues as long as there is supply of water at the soil surface either by direct precipitation or by flowing sheet of water. The estimation and/or measurement of losses are highly dependent on the dominant runoff generation mechanisms of a catchment.

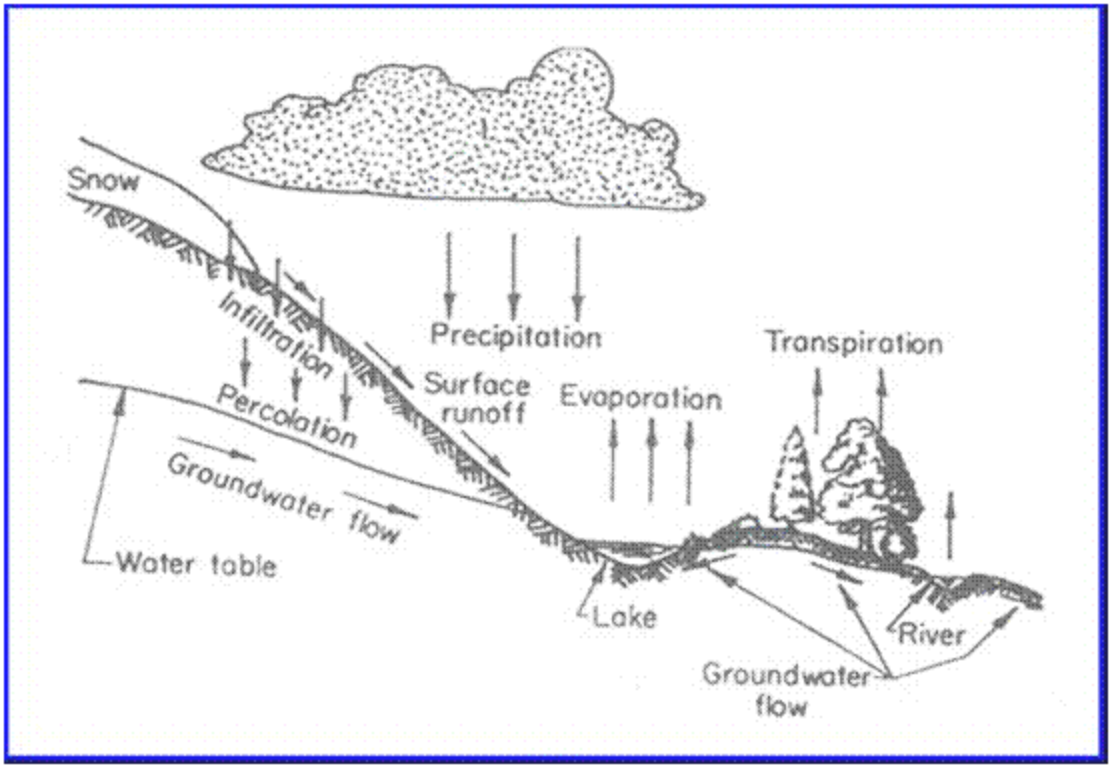

Figure 4.1: *Conceptualization of Storm Losses (Chow, 1964)*

During estimation of runoff from a catchment on monthly or annual basis, the dominant loss components are: evapotranspiration and infiltration. The most commonly adopted loss estimation functions are: (i) infiltration indices, (ii) empirical relationships, and (iii) percentage runoff. Infiltration indices in general express infiltration as an average rate throughout the storm. The simplest of these is the **Φ-index** defined as the rate of rainfall above which the rainfall volume equals the runoff. Secondly, the empirical relationships are derived making use of observed rainfall-runoff data, and a well known and well practiced relationship is the **Soil Conservation Service** (SCS, 1972) loss equation involving single parameter of curve number (CN) based on soil types, land use and soil moisture conditions. Thirdly, the percentage runoff method also known as constant percentage method assumes the losses to be proportional to the rainfall intensity. Out of all three cases, the SCS loss relationship is more suitable for the conditions where observed runoff record is not available as is the case in the present study. Whereas for the other two

cases (infiltration indices and percentage method), some knowledge of observed runoff is needed to estimate the parameters for derivation of respective loss function.

4.2 Methodology

The entire Pothwar region is comprised of three major river basins comprising more than 70% of area including Soan, Haro and Kanshi; three small basins (Bunha, Kahan and Reshi); and few open areas draining directly into Rivers Indus and Jhelum. Therefore, the runoff potential has been estimated on basin levels and then aggregated to find the total runoff potential.

In order to estimate the runoff potential, three different methods have been used. The methods include: (i) SCS loss equation; (ii) locally developed monthly rainfall-runoff relationship; and (iii) estimation of infiltration and evapotranspiration using appropriate relationship(s). The reason for using three different methods was to compare the results and get more confidence about the estimates.

The necessary data required for the above relationships were collected including: monthly rainfall record from several stations in the region; mean monthly temperature at several locations; physiographic and land use data; and necessary maps. The data were obtained from Water and Power Development Authority, Irrigation and Power Department, Pakistan Meteorological Department, Punjab Planning Department, Statistics Department and Survey of Pakistan. The rainfall and runoff data pertain to 1953 to 2005 (Annexure-II).

All the necessary data and information from the maps were processed using the relevant methods to estimate the runoff potential. The detailed description is given in the coming section.

4.3 Rainfall-Runoff Analysis

4.3.1 Runoff Potential Using SCS Loss Equation

The US Soil Conservation Service (SCS, 1972) developed an empirical method using the observed rainfall-runoff data for obtaining runoff losses over the finite areas. This procedure gives the runoff value from the total precipitation minus infiltration using the following relationship:

$$Q = \frac{(P - I_a)^2}{(P - I_a + S_r)} \qquad (4.1)$$

Where

P total rainfall (mm)

Q runoff volume (mm)

I_a initial abstraction (mm)

S_r the potential maximum retention (mm)

The initial abstraction "I_a" is taken as:

$$I_a = 0.2\, S_r \qquad (4.2)$$

And the potential retention S_r is given by the equation:

$$S_r = \frac{1000}{CN} - 10 \qquad (4.3)$$

Where

CN curve number: a parameter dependent on soil type, land cover and antecedent moisture conditions (dimensionless).

First of all, average monthly rainfall for each basin in Pothwar was determined using Isohytel Average Rainfall Method. Then weighted average curve number

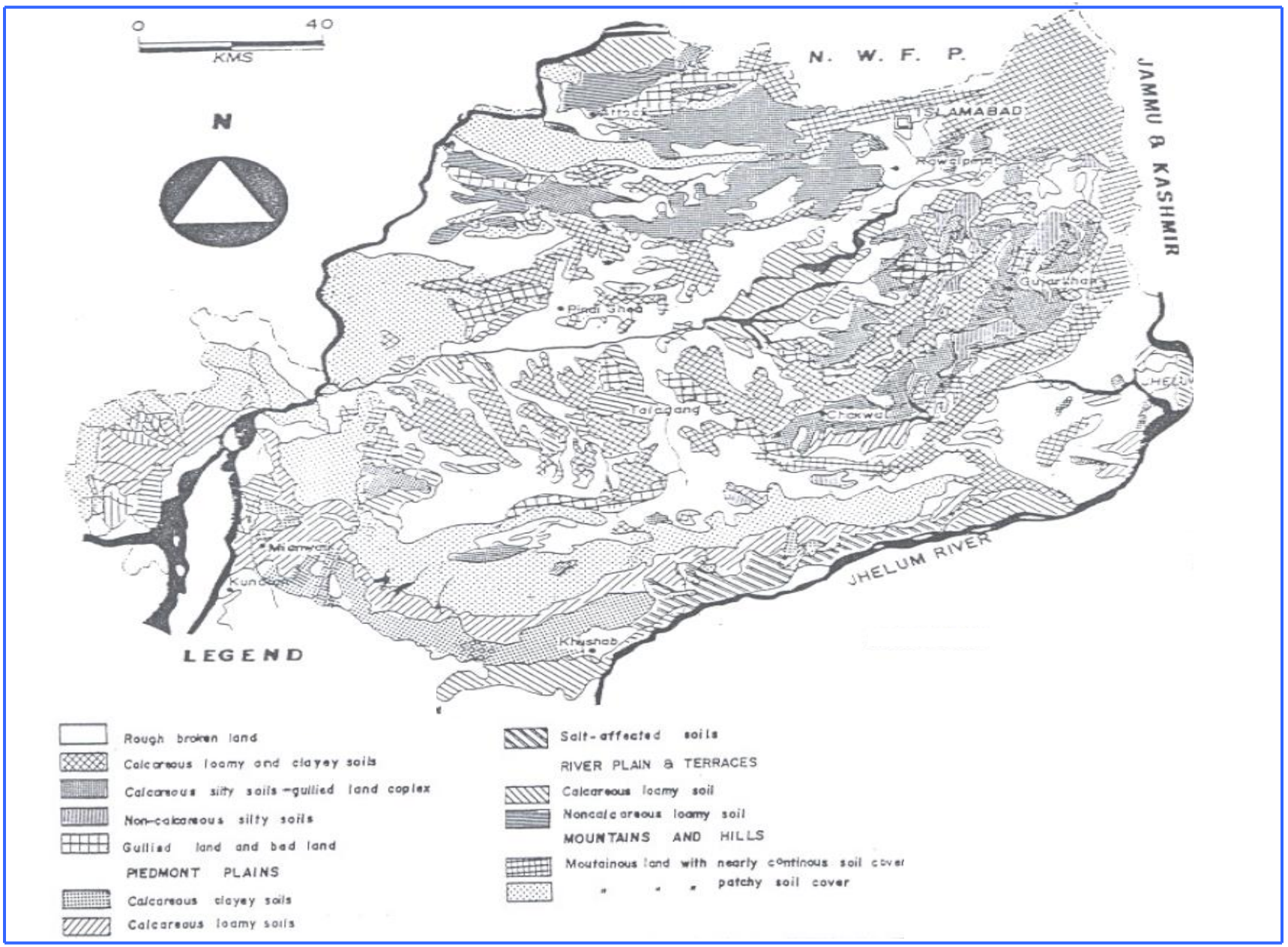

Figure 4.2: *Soil Map of Pothwar Region (including Salt Range)*

was determined for each basin from Figure 4.2, land use and parameters defined in Annexure-III. Then using equations 4.1 to 4.3, the runoff potential from all parts of Pothwar was estimated as given in Table 4.1. In order to take effect of temperature variation over the entire area (Figure 4.3) and resultant antecedent soil moisture conditions (AMC) during the year, the weighted curve number (CN) varied on monthly basis over the year as projected in Figure 4.4. The total annual runoff potential is 4979 MCM (4.03 MAF).

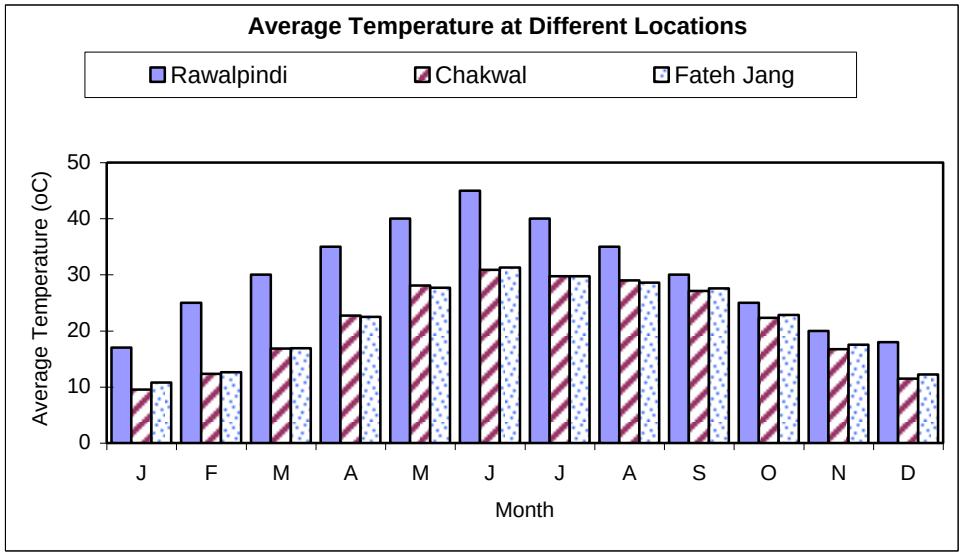

Figure 4.3: *Monthly Temperature Pattern in Different Parts of Pothwar*

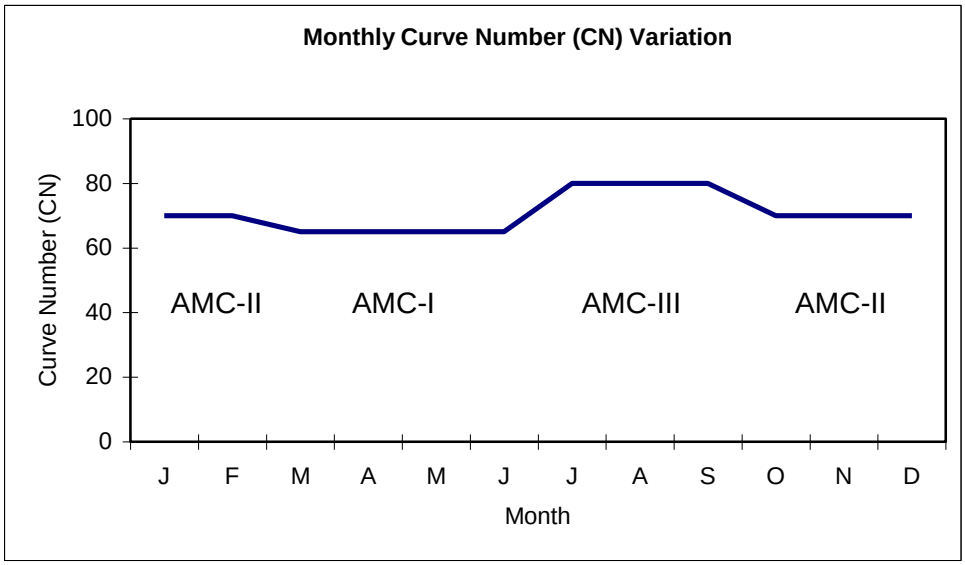

Figure 4.4: *Monthly Curve Number (CN) Pattern based on Soil Moisture Conditions*

Table 4.1: *Runoff Potential from Pothwar by SCS Method*

S.No.	Basin/Area	Area (km^2)	Weighted Curve Number (CN)	Runoff Potential (MCM)
1	Soan Basin	10,622	74 (AMC-III) 62 (AMC-II) 37 (AMC-I)	2,542
2	Haro Basin	1,725	68 (AMC-III) 55 (AMC-II) 29 (AMC-I)	436
3	Kanshi Basin	1,534	70 (AMC-III) 57 (AMC-II) 31 (AMC-I)	467
4	Bunha Basin	1,590	70 (AMC-III) 58 (AMC-II) 32 (AMC-I)	123
5	Kahan Basin	1,398	69 (AMC-III) 56 (AMC-II) 30 (AMC-I)	468
6	Reshi Basin	1,432	68 (AMC-III) 55 (AMC-II) 29 (AMC-I)	263
7	Other open areas (To Jhelum River)	2,368	71-80 (AMC-III) 59-70 (AMC-II) 33-46 (AMC-I)	460
8	Other open areas (To Indus River)	1,331	70 (AMC-III) 58 (AMC-II) 32 (AMC-I)	220
Total (MCM)		**22,000**		**4,979**
Total (MAF)				**4.03**

N.B. AMC-III (saturated/Jul-Sep); AMC-II (average/ Oct-Feb); AMC-I (dry/ Mar-Jun)

4.3.2 Runoff Potential Using SDO Monthly Relationships

Punjab Small Dams Organization developed monthly rainfall-runoff relationships for different parts of Pothwar using rainfall data (1954-83) from seven meteorological stations (Rawalpindi, Fateh Jang, Murree, Gujar Khan, Talagang, Jhelum, Khewra) and runoff data from three small streams of Bishan Dur Khas neas Missa, Sil River near Chahan and Ling river near Kahuta. The developed relationships are described below:

$$R = 0.893 \text{ x } 10^{-7} (P + 112.6)^{3.5} \quad (4.4)$$

$$R = 0.922 \text{ x } 10^{-2} (P + 21.3)^{1.6} \quad (4.5)$$

$$R = 0.428 \text{ x } 10^{-2} (P + 32.5)^{1.5} \quad (4.6)$$

Where

R Monthly runoff (mm)

P Monthly rainfall (mm)

The equation 4.4 can be applied to the area of the upper Soan basin, the equation 4.5 to the area of the lower Soan, Reshi and Haro basins, and the equation 4.6 to the Kanshi, Kahan and Bunha river basins by dividing the Pothwar into three areas as shown in Figure 4.5. The results are given in Table 4.2 giving total potential of 3,282 MCM (2.66 MAF).

]

Table 4.2: *Runoff Potential from Pothwar by SDO Monthly Relationships*

S.No.	Basin/ Area	Area (km^2)	Equation No.	Runoff Potential (MCM)
1	Soan Basin (upper)	10,622	Eq. 4.4	1,726
	Soan Basin (middle and lower parts)		Eq. 4.5	
2	Haro Basin	1,725	Eq. 4.5	273
3	Kanshi Basin	1,534	Eq. 4.6	202
4	Bunha Basin	1,590	Eq. 4.6	162
5	Kahan Basin	1,398	Eq. 4.6	190
6	Reshi Basin	1,432	Eq. 4.5	165
7	Other open areas (towards Jhelum River)	2,368	Eq. 4.5	421
8	Other open areas (towards Indus River)	1,331	Eq. 4.6	143
Total (MCM)		**22,000**		**3,282**
Total (MAF)				**2.66**

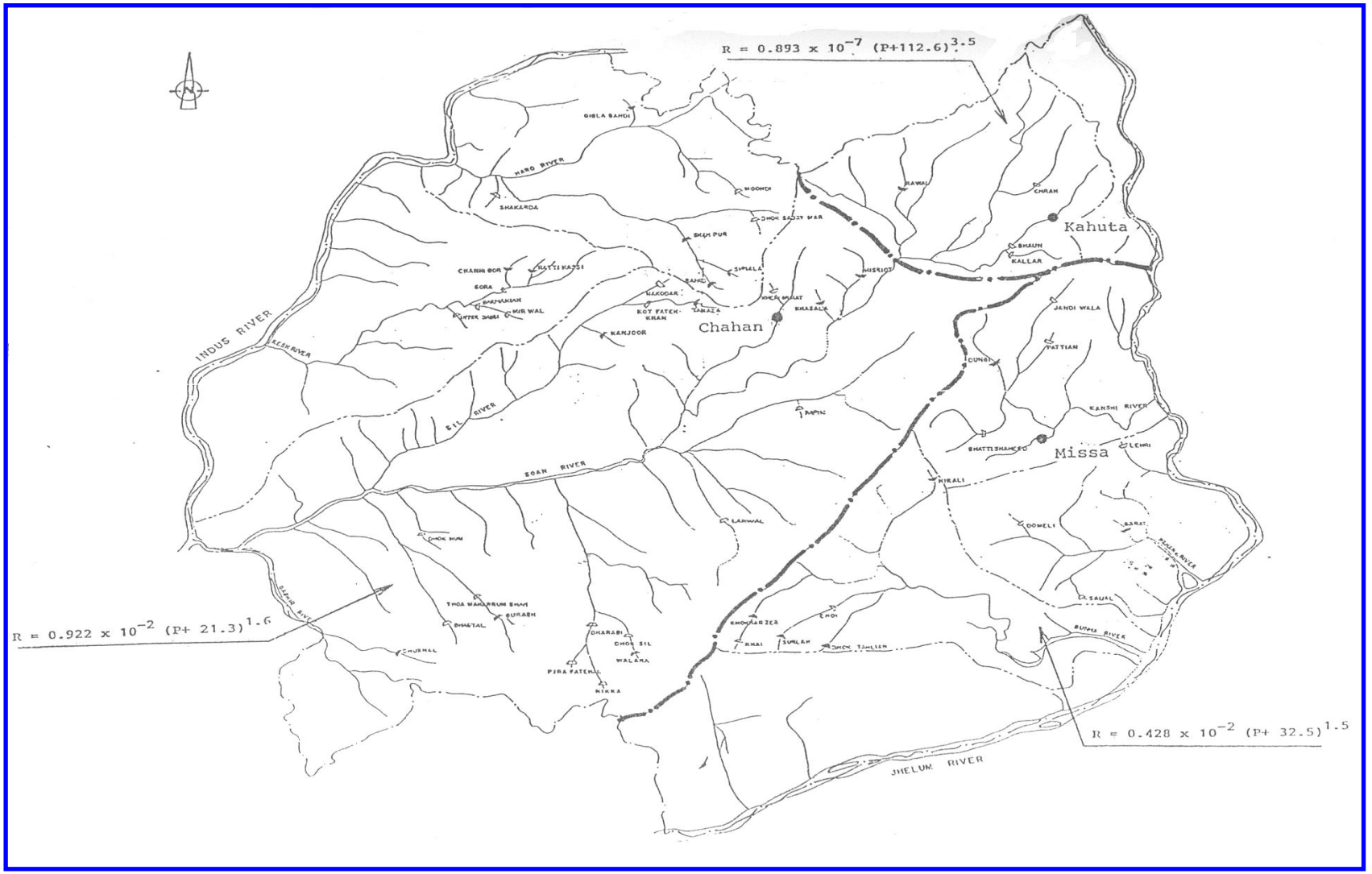

Figure 4.5: *Pothwar Map for Application of Monthly Runoff Equations*

4.3.3 Runoff Potential Using Observed Records

The discharge measurement is another means of having information about the runoff potential from a river basin. There are several discharge measurement points in the region either being or have been monitored by WAPDA and/or Irrigation and Power Department. The long term discharge data were available from WAPDA for large rivers including Soan, Haro and Kanshi which constitute 65% study area. Whereas for small basins including Reshi, Kahan and Bunha, only water levels were available and no rating curves were derived by Irrigation and Power Department. The average annual runoff potential from Soan, Kanshi and Haro river basins are given in Table 4.3. The total annual runoff potential (Soan, Haro and Kanshi) is 4523 MCM (3.66 MAF).

Table 4.3: *Observed Average Runoff Potential from Major Basins of Pothwar*

S.No.	Basin/Area	Area (km^2)	Flow Measurements	Average Runoff Potential (MCM)
1	Soan Basin	10,622	I&P Dept./ WAPDA	3,416 (1960-2005)
2	Haro Basin	1,725	WAPDA	906 (1982-2002)
3	Kanshi Basin	1,534	WAPDA	201 (1982-2002)
4	Bunha Basin	1,590	I&P Dept.	Only water levels are available whereas no rating curves developed by I&P
5	Kahan Basin	1,398	I&P Dept.	
6	Reshi Basin	1,432	I&P Dept.	
7	Other open areas	3,699	No Measurement	-
Total (MCM)		**22,000**		**4,523**
Total (BCM)				**3.66**

Source: WAPDA, Irrigation and Power Department (I&P).

4.4 Discussion

The runoff potential has been estimated from three different methods: one based on a well developed synthetic rainfall-runoff estimation method of SCS; and second a local method developed on the basis of observed rainfall and runoff records from various river basins of the study area. Thirdly, to have some confidence about the estimated values, observed runoff records where available were also analyzed. These methods present variation in the estimates. The main reason for estimates being lower for second method than remaining two is that the equations (4.4 to 4.6) were developed on the basis of average monthly runoff available at the outlet of each basin after compensating for all losses and filling storages available in the catchment area. Whereas the estimates with SCS method provide runoff potential after compensating mainly for infiltration and to some extent for evaporation losses as antecedent moisture conditions have some relevance with evaporation. Further reliability of these estimates was gained from observed runoff record available from various basins in the area. On average the runoff potential is about 4979 MCM (4.03 MAF) in the area. The earlier estimates (Bhutta, 1999; Bhutta *et al*., 2002) quote a figure of 4320 MCM (3.50 MAF). However, the present study is based on detailed analysis at sub-basins levels and some evidence from observed records supporting its outcomes.

CHAPTER 5

IMPACT EVALUATION OF WATER RESOURCES ACTIVITIES

5.1 General

Water resources developments and management activities were carried out in Pothwar region by public sector as an alternative to large scale rainfed agriculture to increase food production and to enhance rural livelihoods. The major activities included: small and mini dams, storage ponds, dug wells, deep turbines, lift schemes, sprinkler and trickle irrigation systems etc. Several impact evaluation studies had already been conducted in the area as already described in Chapter 2, most of which were carried out for specific project or for certain activity or part of the region. The results of such studies were therefore limited to specific project, activity or area. The current study was carried out to evaluate impacts of all type of water resources development activities implemented for agriculture development in the entire region. The outcome of the study provided information about the contribution level of all those developments to enhance productivity as well as the cultivated area.

5.2 Methodology

The approach adopted in the current study was to interact directly with the farmers to get information regarding the water resources activities developed at their farms by the public sector. The information was collected from a carefully selected sample of farmers through a well designed and tested questionnaire. The selection of sample and questionnaire development are described below.

5.2.1 Data Collection and Selection of Sample Size

The list of all water resources activities developed in the region so far is given in Table 5.1. For all impact evaluation purposes, it is appropriate to select a reasonable number of sample size for a particular activity. The sample was therefore so selected that reasonable set of information along with the areal

coverage of the region could be achieved and based on TORs. The design of field survey was selected taking care of number of activities developed in certain district/ tehsil as well as size and/or capacity of the activity. The sample size for each activity is given in Table 5.1.

Table 5.1: *Selected Sample of Activities for Assessment (as per TORs)*

S. No.	Activity	Total (Nos.)	Sample for Survey (Nos.)
1	Small Dams	44	07 (2 large, 3 medium, 2 small)
2	Mini Dams+ Ponds	931+ 1441	30
3	Dug Wells	2163	50
4	Lift Schemes	979	30
5	Potable Sprinkler System	400	20
6	Drip/Trickle System	140	20
7	Erosion Control Structures – Outlets	-	10
8	Erosion Control Structures – Retaining Walls/Spurs	-	10

5.2.2 Development and Testing of Questionnaire

In order to get information directly from the farmers, a questionnaire was developed. The major components of the questionnaire include: general information; cultivated area before and after; change in cropping pattern, agronomic practices, irrigation methods, yield of various crops; change in farm income; and farmers observations for further improvement. The general information of the developed activity included: location, year of construction, capacity/discharge, subsidy paid by the government,

operational status etc. The developed questionnaire was tested in the field through sample survey and the necessary amendments were made.

5.2.3 Participatory Appraisal Survey

The field survey was conducted through developed questionnaire for collection of information directly from the farmers by a team comprising: Junior Engineer with engineering background in water resources, Sociologist and support staff. The survey was conducted on the basis of sample design however the farmers were approached at random and on the basis of total activities developed in each district so that sample could be representative of the entire area.

5.2.4 Data Processing and Analysis

The data collected through questionnaire survey was recorded in SPSS database computer software. This software not only helps data storage but also to perform various statistical tests and analysis. The results of the impact evaluation survey are described as follows.

5.3 Results and Discussion

The results from the analysis of information gathered from the field survey through questionnaire are discussed below in terms of: status of activities; role in enhancing crop productivity and cultivated area; agronomic practices and irrigation methods; and contribution in increasing farm income:

5.3.1 Impacts of Water Resources Activities

On the basis of information collected directly from the field, the impacts of water resources activities were evaluated in terms of change in cropping pattern, increase in cropping intensity, crop yield and farm income.

5.3.1.1 Status of Monitored Water Resources Activities

The overall analysis showed that most of the monitored activities are being utilized (Table 5.2) although their rate of utilization varied from area to area due to several reasons such as: less interest by some farmers, flaws in the selection of site, lack of knowledge and back up support. However, most of the systems of sprinkler and trickle irrigation installed by various agencies were either completely abandoned or deteriorated within few years. The major factors in the failure of the high efficiency irrigation systems were: (i) the lack of information about the system, (ii) non-availability of local material (iii) no back up support (vi) lack of design capabilities (vii) small land holdings (viii) lack of knowledge about irrigation scheduling, and (ix) farmer's misconceptions about the system.

Table 5.2: *Utilization/ Physical Status of Monitored Activities*

S.No.	*Activity*	*Physical Status of Activity*	
		In Working Condition (%)	*Not in Working Condition/ Use (%)*
1	Small Dams	100	-
2	Mini Dams/ Ponds	87	13
3	Dug Wells	95	05
4	Lift Schemes	100	-
5	Potable Sprinkler System	12	88
6	Drip/Trickle System	10	90

5.3.1.2 Impact on Cropping Pattern

The change in cropping pattern has been observed as the farmers due to availability of water are moving from traditional rainfed agriculture to irrigated farming involving cash crops like vegetables, fruits, oilseed, fodder (Table 5.3). However, in some cases farmers are not fully using the developed resources due to

financial limitations, management issues and lack of knowledge/ back up support as described earlier.

Table 5.3: *Impacts on Cropping Pattern*

S.No.	*Activity*	*Cropping Pattern*	
		Growing Crops Before Construction	*Growing Crops After Construction*
1	Small Dams	Wheat, fodder, bajra	Wheat, maize vegetables, fodder
2	Mini Dams/Ponds	Wheat, fodder, maize, peanut	Wheat, maize, vegetables, fodder, peanut
3	Dug Wells	Wheat, bajra	Wheat, maize, vegetables, fodder, peanut
4	Lift Schemes	Wheat, maize	Wheat, vegetables, orchard, fodder
5	Potable Sprinkler System	Wheat, pulses	Wheat, oilseed, vegetables
6	Drip/Trickle System	Wheat	Intercropping (wheat+orchard)

5.3.1.3 Impacts on Cropping Intensity

The availability of water significantly helped improve the cropping intensity as the farmers started growing cash crops like vegetables, fruits and other crops on their lands previously not being utilized due to shortage of water or by adding new land. The cropping intensity increased even upto 180 to 200% which was previously even less than 100% (Table 5.4). However, in some cases, the developed resources are still being under utilized due to numerous issues like lack of farmer interest and knowledge; inefficient agriculture extension services and back up support, price hike for agriculture inputs etc.

Table 5.4: *Impacts on Cropping Intensity*

S.No.	*Activity*	*Average Cropping Intensity*	
		Before (%)	*After (%)*
1	Small Dams	100 (< 100 to 150)	150 (100-200)
2	Mini Dams/Ponds	100 (< 100 to 150)	150 (100-180)
3	Dug Wells	100 (< 100 to 150)	150 (100-200)
4	Lift Schemes	< 100 (0-100)	160 (100-200)
5	Potable Sprinkler System	<100	150 (150-180)
6	Drip/Trickle System	< 100	120 (100-150)

5.3.1.4 Impacts on Crop Yield

The impact of developed activities on crop yield was analyzed particularly for major crops like wheat (Table 5.5). On average 50% increase in crop yield has been observed although some farmers are getting yield equivalent to irrigated areas. Since no crop was successfully grown with drip/trickle system, therefore no data on yield could be retrieved from the respective farmers interviewed.

Table 5.5: *Impacts on Crop Yield (based on Wheat Crop)*

S.No.	*Activity*	*Wheat Yield*	
		Before (kg/ha)	*After (kg/ha)*
1	Small Dams	800 - 1600	2500 (1800-3200)
2	Mini Dams	< 1500	2800 (1800-3200)
3	Dug Wells	800 -1600	2400 (1600-3000)
4	Lift Schemes	800 -1600	3000 (2000-3400)
5	Potable Sprinkler System	< 1500	2600 (2000 – 2800)
6	Drip/Trickle System	< 1500	-

5.3.1.5 Impacts on Farm Income

Due to change in cropping pattern and cropping intensity, some increase in farm income has been reported by the farmers average 30 to 50% depending upon the yield and crops being grown. The farmers growing vegetables are getting more income due to the water available most of the year from the developed resources.

5.3.2 Impacts of Soil Conservation Activities

On the basis of information collected directly from the field, the impacts of soil conservation activities were evaluated in terms of erosion control, increase in cropping intensity, crop yield and farm income. The evaluation showed that the development of soil conservation activities including water disposal outlets, retaining walls and spurs helped erosion control (Table 5.6) from agricultural lands. The soil conservation resulted in increased cultivated area, improved cropping pattern, crop yield and so the farm income. However, in some cases the non-maintenance of developed structures further deteriorated the land conditions.

Table 5.6: *Impacts of Soil Conservation Activities*

S.No.	*Parameters*	*Impacts (%)*
1	Erosion Control	70
2	Cultivated Area (acres)	25
3	Cropping Intensity (%)	35
4	Crop Yield (kg/ha)	20
5	Farm Income (Rs)	15

5.4 Major Findings

The overall observation is that although the impacts of the water resources developed and soil conservation activities are limited but these activities contributed to bring about improvement in cropping pattern; increased cultivated area, crop yield and farm income; and land management by erosion control. The overall increase in cultivated area is not significant although some of the rainfed areas came under irrigated agriculture due to construction of small and mini dams as well as dugwells in the area.

Almost all of the high efficiency systems installed in the area either completely abandoned or deteriorated within few years. The major factors in the failure of the high efficiency irrigation systems were: (i) the lack of information about the system, (ii) non-availability of local material (iii) no back up support (vi) lack of design capabilities (vii) small land holdings (viii) lack of knowledge about irrigation scheduling and (ix) farmer's misconceptions about the system.

However, still most of the agriculture is practiced on traditional methods and dependent on rainfall as the developed water resources facilities are not being utilized to their full potential due to several reasons including: institutional issues with development agencies, farmers financial limitations, lack of farmers' interest, and lack of knowledge and back up support.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

On the basis of analysis of collected information and field data, it may be inferred that:

- Sufficient water resources development and soil conservation activities took place in Pothwar region within last three decades.
- There have been constructed 44 small and 900 mini dams along with large number of dugwells, tubewells and lift pumps under various schemes so far.
- The evaluation of water resources development and soil conservation activities showed that although the impacts are limited but these activities contributed to bring about improvement in cropping pattern; increased cultivated area, crop yield and farm income; and land management by erosion control.
- Almost all of the sprinkler and trickle irrigation systems installed in the area were either abandoned or deteriorated within few years due to various technical reasons, lack of knowledge and back up support.
- The assessment of runoff potential from various methods indicated that total average runoff generation is about 4979 MCM (4.03 MAF) from different river basins. All developed rainwater harvesting activities captured only 173 MCM (0.140 MAF) leaving sufficient potential, out of which if 50% is utilized would meet not only present but futuristic domestic and agricultural demand.
- Most of the developed water resources activities are being under utilization due to various institutional issues and communication gaps.

6.2 Recommendations

The recommendations are as follows:

- In order to utilize available land and water resources more efficiently, there is need to develop a strategic plan based on short, medium and long term initiatives defining site-specific water resources and erosion control activities.
- The existing small and mini dams need to be utilized to their full potential to enhance the cropped area as well as cropping intensity. At present, these are not being utilized effectively.
- In order to increase the cultivated area, the efficient land and water management techniques need to be promoted for agriculture development. These include: conserving more moisture during rainy season, low cost erosion control methods, drought resistant and high yielding varieties, watershed management, etc.
- An awareness campaign should be launched to make the general masses aware about water conservation and need based utilization of available water resources coupled with strong back up support.

REFERENCES & BIBLIOGRAPHY

ACE (1963). Soan basin reconnaissance report, Associated Consulting Engineers, 1963, Lahore.

Anwar, C. M. *et al*. (1986). Management of gully eroded areas in Pothwar, Pakistan Agricultural Research Council (1986), p.1.

Ashfaq, A., Ashraf, M. and Khokhar, M.I.A. (2003). Integrated land and water resources management in Pothwar: Issues and Options. *Science International*, 15(1): 87-92.

Ashraf, M., F.U. Hassan, A. Saleem and M. I. Lone (1999). Water resources development and its management in the Barani areas of Punjab, Proceeding: Water resources achievements and issues in 20th century and challenges for the next Millennium, June 28-30, 1999, PCRWR, Islamabad.

Ashraf, M., F.U. Hassan, A. Saleem and M. Iqbal, (2002). Soil conservation and management: A pre-requisite for sustainable agriculture in the Pothwar, J.of Sci., Tech. and Dev., 21(1), 2002, 25-31.

Ashraf, M., Kahlown, M.A., and Ashfaq, A. (2007). Impact of small dams on agriculture and groundwater development: A case study from Pakistan, Journal of Agricultural Water Management, 92(2007), pp. 90-98, July 2007.

Azhar, A.M. (1995). Yields in canal command areas, Journal of Engineering and Applied Sciences, 4(1), 109-116.

Bhatti, M.A., M.A. Cheema and G.V. Skogerboe (1999). Maintenance and operational activities in Shahpur and Mirwal small dams, International Irrigation and Management Institute, Lahore.

Bhutta, I.A. (1999). Achievements and issues in 20th century in Small Dams (Rainwater Harvesting). In Proceedings of the national workshop on water resources achievements and issues in 20th century and challenges for the next millennium. Pakistan Council of Research in Water Resources, Islamabad-Pakistan, pp.64-69.

Bhutta, M.N., M.R. Chaudhry, M. Sindhu (2002). Rainwater harvesting impact on agriculture in Pakistan, In Proceedings of the National symposium on drought and water resources in Pakistan, 18th March 2002, CEWRE, Lahore, Pakistan.

Cheema, M.A., Bandaragoda D.J. (1997). Base line survey for farmers organizations of Mirwal and Shahpur small dams, Punjab, Pakistan. International Irrigation Management Institute, Report No. R-38. Directorate Land Records, 1981, Lahore.

IIMI (1999). Social organizations for improved system management and sustainable irrigation agriculture in small dams (Inception report), International Irrigation Management Institute, Lahore.

Iqbal, M.S. and S.A. Shahid (1992). An assessment of agricultural development in the rehabilitated small dams command area. Punjab Economic Research Institute, Lahore.

Iqbal, M.S. (1989). Baseline survey of Shahpur Small Dam. Punjab Economic Research Institute, Lahore. Publication No.257.

Ismail, M. (1983). Hydrogeologic investigations in Eastern Drainage Basin, Pothwar Plateau, Punjab Province, GWI Report No. 43, WAPDA, December 1983, Lahore.

Kahlown and Majeed (2004). Water Resources Development and Management in Pakistan, (ed), PCRWR 2004.

Kazi, M.A. and Hanif, M. (1980). Availability of groundwater in selected sectors/areas of Islamabad, Phase-I &II.

Kazi, M.A. and Khan, A.Q. (1977). Hydrogeologic reconnaissance of Soan River Basin. 1977.

Khan, L.A. and Ismail, M. (1982). Hydrogeologic investigations in Soan Basin, Pothwar Plateau, Punjab Province, GWI Report No. 3, WAPDA, August 1982, Lahore.

Khan, L.A., Ashraf, M. and Ismail, M. (1981). Hydrogeologic investigations in Haro River Basin, Pothwar Plateau, Punjab Province, GWI Report No. 36, WAPDA, April 1981, Lahore.

Khan, M. J., Ashraf, M. and Saleem, M.A. (1999). Evaluation of second barani area development project, Punjab Economic Research Institute (PERI), May 1999, Lahore, Punjab.

Khan, M.J. (1988). Screening survey of potential small dams sites in Punjab, Punjab Economic Research Institute (PERI), Publication No. 242, July 1988, Lahore, Pakistan.

Khan, M.J., Khan, M.A., Ashraf, M and Shahid, A.S. (1988). Screening Survey of Potential Small Dam Sites in Punjab, Punjab Economic Research Institute (PERI), Publication No. 242, July 1988, Lahore, Punjab.

Khan, S.R.A. (2001). Crop Management in Pakistan (ed), Directorate of Agricultural Information, Punjab Lahore, September 2001.

Manual for Design of Small Dams, Small Dams Organization, Department of Irrigation and Power, Government of Punjab.

Marshall, T.J and J. W. Holmes (1988). *Soil Physics, 5th Edition*, John Wiley, New York.

MINFAL (2006). Agricultural Statistics of Pakistan, Ministry of Food Agriculture and Livestock (MINFAL), Islamabad, Pakistan, 2005.

Mutreja, K.N. (1990). Applied Hydrology (Ed.), Tata McGraw Hill Publishing Company Limited, New Delhi, India.

NESPAK (1991). Evaluation of small dams in Punjab and N. W. F. P. Volume II-Part A-C, Government of Pakistan, Ministry of Planning and Development Division.

NESPAK, Harza Engineering Company and Development Alternatives Inc. (1988), Master Plan for Barani Area Development, Volumes I to III, April 1988.

PPDD (1987). Master Plan for barani area development project: Interim Report Vol. II, Inventory and Analysis, Punjab Planning and Development Department (PPDD), March 1987, Lahore.

Punjab Barani Commission (1976). Report of Punjab Barani Commission, Government of Punjab, Lahore, June 1976.

SCS (1972). National Engineering Handbook, Section 4, Hydrology, US Department of Agriculture, Soil Conservation Services, Washington DC, USA.

Shafiq, M., (2001). Rainwater harvesting for sustained agriculture production, J. of Sci., Tech. and Dev., Vol. 20 (1), March 2001, Islamabad.

Shafiq, M., M.Z. Ikram, S. Ahmad and A. Nasir (1996). Surface runoff and soil loss under cropped fields of medium rainfall zone of Pothwar Plateau, J. Eng. Appl. Sci., Vol. 15, No. 2, July-Dec 1996.

Shah H. N. (1984). An evaluation of Small Dams Programme in Punjab. Punjab Economic Research Institute, Lahore Publication No.213.

Shahid S.A., M. Ashraf, K. Ata, Mazhar-ul-Haq (1996). Evaluation of Small Dams Project in Punjab. Punjab Economic Research Institute.

Sheikh, A. A., Ashraf, M. and Bahzad, A. (2007), Water Resources Assessment and Development of Strategic Water Utilization Plan in Pothwar Region for its Sustainable Management, PCRWR Research Report No. 7-2007, Islamabad.

Sheikh, A.D., D. Byarlee and M. Azeem (1988). Factors affecting cropping intensity in Barani areas of Northern Punjab, Pakistan, Pak. J. Agric. Soc. Sci., 2, 53-59.

WAPDA (1979). Hydrogeology of Hazro Area, Pothwar Plateau, Groundwater Hydrology Project, WAPDA, February 1979, Lahore.

WAPDA (1982). Hydrogeologic Survey of Soan Basin, Hydrogeologic Directorate of WAPDA, Lahore.

WRRI (1995). Participatory research and development, Fateh Jang Field Station, Water Resources Research Institute, National Agricultural Research Centre, Islamabad, 1995.

ANNEXURE

Annexure-I

Questionnaire Survey for Impact Assessment of Water Resources Activities

(For Mini Dams)

Name of Mini Dam				
Location/ Mauza/Tehsil/ District				
Longitude		**Latitude**		
Year of construction of Mini dam		**Type of mini dam:**		
		Stone Masonry		
		Earthen with side spillway		
Sponsorship	100% Government Share	Government share: Farmer share:		100% Farmer Share
Storage capacity (acre-feet)		**Catchment area (sq mile)**		
Inflow to dam	Perennial		Non-perennial	
Is dam filled every year	Yes		No Give reason: how much filled and why:	
How is irrigation applied	By gravity flow	By lift		Partly lift and partly gravity
Is there problem of silt	No	Appeared after some years		Completely or partly silted
Total designed command area of dam (acres)			**Area being benefited so far (acres)**	

Total cultivated area before construction of small dam		**Cultivated area after construction of small dam**	
Is dam water sufficient to irrigate all land	Yes	No Why and how much area is being irrigated:	Surplus water available
Is fish growing involved	Yes	No	Planning in near future
Cropping intensity before		**Cropping intensity after**	
1. Single crop per year: 2. One major crop and one short period crop: 3. Two crops per year:		1. Single crop per year: 2. One major crop and one short period crop: 3. Two crops per year	

Major crops before dam construction			**Major crops after dam construction**		
Crop	Area (kanals)	Avg. Yield	Crop	Area (kanals)	Avg. Yield

Growing fruit before dam			**Growing fruits after dam**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Growing vegetables before dam	**Growing vegetables after dam**

Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield
Method of irrigation before dam			**Method of irrigation after dam**		
Crops	Flooding: Furrows: Sprinkler: Rainfed:		Crops	Flooding: Furrows: Sprinkler: Rainfed:	
Vegetables	Flooding: Furrows: Sprinkler: Rainfed:		Vegetables	Flooding: Furrows: Sprinkler: Rainfed:	
Fruits	Flooding: Furrows: Sprinkler: Rainfed:		Fruits	Flooding: Furrows: Sprinkler: Rainfed:	
Livestock before dam			**Livestock after dam**		
Name	Number		Name	Number	
Average annual income before dam (Rs)			**Average annual income after dam (Rs)**		
Crops			Crops		
Vegetables			Vegetables		
Fruits			Fruits		

Livestock		Livestock	
Other farm source		Other farm source	
Off farm income		Off farm income	
Total		**Total**	
Farmer's observations/comments/suggestions:			

Questionnaire survey for impact assessment of water resources activities

(For Dug well/Open well)

Name of Farmer					
Location/ Mauza/Tehsil					
Longitude		**Latitude**			
Year of construction of dugwell		**Type of dugwell**			
		Earthen			
		Brick masonry			
		Pre-cast RCC rings			
		Hard rock			
Sponsorship	100% Government Share	Government share: Farmer share:			100% Farmer Share
Depth of dugwell (ft)		**Depth of water level (ft)**			
Water level behaviour	Never changes	Maximum after monsoon and dry before monsoon	Fluctuates during the year with average drop (ft)	Water level falling every year	Dried out
How is water lifted	Manually	By Persian wheel	By electric motor	By pump fitted with diesel engine	
Is water good in taste	Yes	No	Taste changed bad after sometime		
Total Land of Farmer at the site		**Area not under any use**			
Cultivated area before construction of dugwell		**Cultivated area after construction of dugwell**			
Is dug well water sufficient to irrigate all land	Yes	No Why and how much area is being irrigated:	Surplus water available		

Cropping intensity before		**Cropping intensity after**	
1. Single crop per year: 2. One major crop and one short period crop: 3. Two crops per year:		1. Single crop per year: 2. One major crop and one short period crop: 3. Two crops per year:	

Crops grown before dugwell construction			**Crops growing after dugwell construction**		
Crop	Area (kanals)	Avg. Yield	Crop	Area (kanals)	Avg. Yield

Growing fruit before dugwell			**Growing fruits after dugwell**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Growing vegetables before dugwell			**Growing vegetables after dugwell**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Method of irrigation before dugwell		**Method of irrigation after dugwell**	
Crops:	Flooding: Furrows: Sprinkler: Rainfed:	Crops:	Flooding: Furrows: Sprinkler: Rainfed:

Vegetables	Flooding: Furrows: Sprinkler: Rainfed:	Vegetables	Flooding: Furrows: Sprinkler: Rainfed:
Fruits	Flooding: Furrows: Sprinkler: Rainfed:	Fruits	Flooding: Furrows: Sprinkler: Rainfed:

Livestock before dugwell		**Livestock after dugwell**	
Name	Numbers	Name	Numbers

Average annual income before dugwell (Rs)		**Average annual income after dugwell (Rs)**	
Crops		Crops	
Vegetables		Vegetables	
Fruits		Fruits	
Livestock		Livestock	
Other farm source		Other farm source	
Off farm income		Off farm income	
Total		**Total**	

Farmer's observations/comments/suggestions:

Questionnaire survey for impact assessment of water resources activities

(For Small Dam)

Name of Dam				
Name of Farmer				
Location/ Mauza/Tehsil/ District				
Longitude		**Latitude**		
Year of construction of small dam		**Type of small dam:**		
		Stone Masonry		
		Earthen with side spillway		
Sponsorship	100% Government Share	Government share: Farmer share:		100% Farmer Share
Storage capacity (acre-feet)		**Catchment area (sq mile)**		
Inflow to dam	Perennial		Non-perennial	
Is dam filled every year	Yes		No Give reason: how much filled and why:	
Is there problem of silt	No	Appeared after some years		Completely or partly silted
How is irrigation applied	By gravity flow	By lift		Partly lift and partly gravity
Total design command area			**Area not under any use**	
Total farmers in the command area			**Total farmers being benefited from dam**	
Canal/ irrigation channel length			**How many farmers benefiting from the channel**	
Is dam water sufficient to irrigate all	Yes	No		Surplus water available

land		Why and how much area is being irrigated:	
Cultivated area before construction of dam		**Cultivated area after construction of dam**	
Is fish growing involved	Yes	No	Planning in near future
Cropping intensity before		**Cropping intensity after**	
1. Single crop per year: 2. One major crop and one short period crop: 3. Two crops per year:		1. Single crop per year: 2. One major crop and one short period crop: 3. Two crops per year:	

Major crops before dam construction			**Major crops after dam construction**		
Crop	Area (kanals)	Avg. Yield	Crop	Area (kanals)	Avg. Yield

Growing fruit before dam			**Growing fruits after dam**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Growing vegetables before dam			**Growing vegetables after dam**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Method of irrigation before dam		**Method of irrigation after dam**	
Crops	Flooding: Furrows: Sprinkler: Drip: Rainfed:	Crops	Flooding: Furrows: Sprinkler: Drip: Rainfed:
Vegetables	Flooding: Furrows: Sprinkler: Drip: Rainfed:	Vegetables	Flooding: Furrows: Sprinkler: Drip: Rainfed:
Fruits	Flooding: Furrows: Sprinkler: Drip: Rainfed:	Fruits	Flooding: Furrows: Sprinkler: Drip: Rainfed:

Livestock before dam		**Livestock after dam**	
Name	Number	Name	Number

Groundwater levels of dugewells before dam in the periphery		**Groundwater levels of dugewells after dam construction in the periphery**	
Approximate distance from dam	Water level	Approximate distance from dam	Water level

Dam inflow data (from Small Dams)		Dam outflow data (from Small Dams)	
Year	Inflow	Year	Outflow
What are the basis for water charges		**What are the water charges**	**Rs**
Land based Water provided Crop based Fixed			
Average annual income before dam (Rs)		**Average annual income after dam (Rs)**	
Crops		Crops	
Vegetables		Vegetables	
Fruits		Fruits	
Livestock		Livestock	
Other farm source		Other farm source	
Off farm income		Off farm income	
Total		**Total**	
Farmer's observations/comments/suggestions:			

Questionnaire survey for impact assessment of water resources activities

(For sprinkler system)

Name of Farmer				
Location/ Mauza/Tehsil/ District				
Longitude		**Latitude**		
Year of installation		**Type of Sprinkler system:**		
		Portable raingun		
		Fixed type		
Sponsorship	100% Government Share	Government share: Farmer share:		100% Farmer Share
Is system still operational	Yes	Not		Made operational after repair
Model type		**Area of coverage (kanal or acre) as radius**		
Source of water	Rainwater Dam/Pond	Dugwell	Tubewell	Turbine
Power source	By gravity flow	By diesel engine		By electricity
Is system easy to operate	Yes	No		Learnt with passage of time
Total design command area		**Area not under any use**		
Cultivated area before installation of system		**Cultivated area after installation of system**		

Cropping intensity before		**Cropping intensity after**	
1. Single crop per year: 2. One major crop and one short period crop:		1. Single crop per year: 2. One major crop and one short period crop:	

3. Two crops per year:			3. Two crops per year:		
Crops grown before sprinkler installation		**Crops growing after sprinkler installation**		**Crops being grown with sprinkler system**	

Major crops before installation of system			**Major crops being grown with sprinkler system**		
Crop	Area (kanals)	Avg. Yield	Crop	Area (kanals)	Avg. Yield

Growing fruit before sprinkler			**Growing fruits with sprinkler**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Growing vegetables before sprinkler			**Growing vegetables with sprinkler**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Method of irrigation before sprinkler with area coverage		**Method of irrigation after sprinkler with area coverage**	
Crops:	Flooding: Furrows: Rainfed: Other:	Crops:	Flooding: Furrows: Sprinkler: Rainfed:
Vegetables	Flooding: Furrows: Rainfed: Other:	Vegetables	Flooding: Furrows: Sprinkler: Rainfed:
Fruits	Flooding: Furrows: Rainfed: Other:	Fruits	Flooding: Furrows: Sprinkler: Rainfed:

Livestock before sprinkler		**Livestock after sprinkler**	
Name	Number	Name	Number

Average annual income before sprinkler (Rs)		**Average annual income after sprinkler (Rs)**	
Crops		Crops	
Vegetables		Vegetables	
Fruits		Fruits	
Livestock		Livestock	
Other farm source		Other farm source	
Off farm income		Off farm income	
Total		**Total**	

Farmer's observations/comments/suggestions:

Questionnaire survey for impact assessment of water resources activities

(For Drip Irrigation System)

Name of Farmer						
Location/ Mauza/Tehsil/District						
Longitude			**Latitude**			
Year of installation		**Made of drip/trickle system:**				
		Imported				
		Local made				
Sponsorship	100% Government Share	Government share: Farmer share:		100% Farmer Share		
Type of system	Emitter type		Micro tubes		Other (please specify)	
Is system still operational	Yes		Not		Made operational after repair	
Source of water	Rainwater Dam/Pond	Dugwell	Tubewell	Turbine		
Power source	By gravity flow	By diesel engine		By electricity		
Is system easy to operate	Yes	No		Learnt with passage of time		
Total farm area			**Farm area under drip system**			
Drip system installed on mature orchard		**Drip system installed on young orchard**		**Drip system installed on new orchard**		
Is intercropping being done			**Major crops for intercropping**			
Growing fruit before drip system			**Growing fruits with drip system**			
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield	

Growing vegetables before drip			**Growing vegetables with drip**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield
Method of irrigation before drip with area coverage			**Method of irrigation after drip with area coverage**		
Crops	Flooding: Furrows: Rainfed: Other:		Crops	Flooding: Furrows: Sprinkler: Drip: Rainfed:	
Vegetables	Flooding: Furrows: Rainfed: Other:		Vegetables	Flooding: Furrows: Sprinkler: Drip Rainfed:	
Fruits	Flooding: Furrows: Rainfed: Other:		Fruits	Flooding: Furrows: Sprinkler: Drip: Rainfed:	

Livestock before Drip		**Livestock after Drip**	
Name	Number	Name	Number

Average annual income before Drip (Rs)		**Average annual income after Drip (Rs)**	
Crops		Crops	
Vegetables		Vegetables	
Fruits		Fruits	
Livestock		Livestock	
Other farm source		Other farm source	
Off farm income		Off farm income	
Total		**Total**	

Farmer's observations/comments/suggestions:

Questionnaire survey for impact assessment of water resources activities

(For Lift Irrigation System)

Name of Farmer							
Location/ Mauza/Tehsil/ District							
Longitude			**Latitude**				
Year of installation			**Made of lift system:**				
			Imported				
			Local made				
Sponsorship	100% Government Share		Government share: Farmer share:			100% Farmer Share	
Is system still operational	Yes		Not			Made operational after repair	
Total lift upto land			**Average flow of stream/nullah (if available) cusecs**				
Nature of flow from source of water	Perennial flow			Non-perennial flow			
Power source	Fuel less turbine		By diesel engine			By electricity	
Is system easy to operate	Yes		No			Learnt with passage of time	
Total farm area			**Farm area being benefited from lift system**				
Lift system being used for crops		**Lift system being used for orchard**		**Lift system being used for vegetables**		**Lift system for all uses**	
Major crops before lift system				**Major crops after lift system**			
Name	Area (kanals)	Avg. Yield		Name	Area (kanals)	Avg. Yield	

Growing vegetables before lift system			**Growing vegetables after lift system installed**		
Name	Area (kanals)	Avg. Yield	Name	Area (kanals)	Avg. Yield
Growing vegetables before lift system			**Growing vegetables after lift system installed**		
Name	Area (kanals)	Avg. Yield	Name	Area (kanals)	Avg. Yield

Method of irrigation before lift system with area coverage		**Method of irrigation after lift system with area coverage**	
Crops	Flooding: Furrows: Rainfed: Other:	Crops	Flooding: Furrows: Sprinkler: Rainfed:
Vegetables	Flooding: Furrows: Rainfed: Other:	Vegetables	Flooding: Furrows: Sprinkler: Rainfed:

Fruits	Flooding: Furrows: Rainfed: Other:	Fruits	Flooding: Furrows: Sprinkler: Rainfed:
Livestock before lift system installed		**Livestock after lift system installed**	
Name	Number	Name	Number
Average annual income before lift system installed (Rs)		**Average annual income after lift system installed (Rs)**	
Crops		Crops	
Vegetables		Vegetables	
Fruits		Fruits	
Livestock		Livestock	
Other farm source		Other farm source	
Off farm income		Off farm income	
Total		**Total**	
Farmer's observations/comments/suggestions:			

Questionnaire survey for impact assessment of water resources activities

For Soil Conservation Structure (outlet, spillways etc.)

<table>
<tr><td>Name of Farmer</td><td colspan="5"></td></tr>
<tr><td>Location/ Mauza/Tehsil/ District</td><td colspan="5"></td></tr>
<tr><td>Longitude</td><td colspan="2"></td><td>Latitude</td><td colspan="2"></td></tr>
<tr><td rowspan="4">Year of construction</td><td rowspan="4"></td><td colspan="3">Type of soil conservation structure:</td></tr>
<tr><td colspan="2">Stone Masonry</td><td></td></tr>
<tr><td colspan="2">Earthen</td><td></td></tr>
<tr><td colspan="2">Loose stone work</td><td></td></tr>
<tr><td>Sponsorship</td><td>100% Government Share</td><td colspan="2">Government share:
Farmer share:</td><td colspan="2">100% Farmer Share</td></tr>
<tr><td>Size of structure (length x width)</td><td colspan="2"></td><td>Area behind structure (sq mile)</td><td colspan="2"></td></tr>
<tr><td>Inflow to structure</td><td colspan="2">Perennial</td><td colspan="3">Non-perennial</td></tr>
<tr><td>Is structure still working</td><td colspan="2">Yes</td><td colspan="3">No

Give reason:</td></tr>
<tr><td>Is the soil erosion problem controlled</td><td>Yes</td><td colspan="2">No
Give reason</td><td colspan="2">Partly controlled</td></tr>
<tr><td>Total cultivated area behind structure (acres)</td><td colspan="2"></td><td>Area being benefited so far (acres)</td><td colspan="2"></td></tr>
<tr><td>Total cultivated area before construction of structure</td><td colspan="2"></td><td>Cultivated area after construction of structure</td><td colspan="2"></td></tr>
<tr><td colspan="2">Cropping intensity before</td><td colspan="4">Cropping intensity after</td></tr>
<tr><td>1. Single crop</td><td></td><td colspan="2">1. Single crop per</td><td colspan="2"></td></tr>
</table>

per year: 2. One major crop and one short period crop: 3. Two crops per year:		year: 2. One major crop and one short period crop: 3. Two crops per year	

Major crops before dam construction			**Major crops after construction**		
Crop	Area (kanals)	Avg. Yield	Crop	Area (kanals)	Avg. Yield

Growing fruit before			**Growing fruits after**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Growing vegetables before			**Growing vegetables after**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Method of irrigation before		**Method of irrigation after**	
Crops	Flooding: Furrows: Sprinkler: Rainfed:	Crops	Flooding: Furrows: Sprinkler: Rainfed:

Vegetables	Flooding: Furrows: Sprinkler: Rainfed:	Vegetables	Flooding: Furrows: Sprinkler: Rainfed:
Fruits	Flooding: Furrows: Sprinkler: Rainfed:	Fruits	Flooding: Furrows: Sprinkler: Rainfed:

Livestock before		**Livestock after**	
Name	Number	Name	Number

Average annual income before (Rs)		**Average annual income after (Rs)**	
Crops		Crops	
Vegetables		Vegetables	
Fruits		Fruits	
Livestock		Livestock	
Other farm source		Other farm source	
Off farm income		Off farm income	
Total		**Total**	

Farmer's observations/comments/suggestions:

Questionnaire survey for impact assessment of water resources activities

For Soil Conservation Structure (Retaining Walls/ G.I Spurs)

Name of Farmer				
Location/ Mauza/Tehsil/ District				
Longitude		**Latitude**		
Year of construction		**Type of Retaining Wall:**		
		Stone Masonry		
		G.I Spur		
		Loose stone work		
Sponsorship	100% Government Share	Government share: Farmer share:		100% Farmer Share
Size of structure (length x width)		**Area behind structure (sq mile)**		
Inflow to structure	Perennial		Non-perennial	
Is structure still working	Yes		No Give reason:	
Is the soil erosion problem controlled	Yes	No Give reason		Partly controlled
Total cultivated area behind structure (acres)			**Area being benefited so far (acres)**	
Total cultivated area before construction of structure		**Cultivated area after construction of structure**		
Cropping intensity before		**Cropping intensity after**		
1. Single crop per year:		1. Single crop per year:		

2. One major crop and one short period crop: 3. Two crops per year:		2. One major crop and one short period crop: 3. Two crops per year	

Major crops before dam construction			**Major crops after construction**		
Crop	Area (kanals)	Avg. Yield	Crop	Area (kanals)	Avg. Yield

Growing fruit before			**Growing fruits after**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Growing vegetables before			**Growing vegetables after**		
Type	Area (kanals)	Avg. Yield	Type	Area (kanals)	Avg. Yield

Method of irrigation before		**Method of irrigation after**	
Crops	Flooding: Furrows: Sprinkler: Rainfed:	Crops	Flooding: Furrows: Sprinkler: Rainfed:

Vegetables	Flooding: Furrows: Sprinkler: Rainfed:	Vegetables	Flooding: Furrows: Sprinkler: Rainfed:
Fruits	Flooding: Furrows: Sprinkler: Rainfed:	Fruits	Flooding: Furrows: Sprinkler: Rainfed:

Livestock before		**Livestock after**	
Name	Number	Name	Number

Average annual income before (Rs)		**Average annual income after (Rs)**	
Crops		Crops	
Vegetables		Vegetables	
Fruits		Fruits	
Livestock		Livestock	
Other farm source		Other farm source	
Off farm income		Off farm income	
Total		**Total**	

Farmer's observations/comments/suggestions:

Annexure-II

Monthly Average Rainfall of Stations in Pothwar (mm)

Monthly Average (1953-1983)													
Station	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
Rawalpindi	69	66	81	62	40	53	245	299	109	31	21	30	1106
Murree	133	126	155	128	89	118	334	330	154	71	35	59	1732
Fateh Jang	42	42	58	45	29	35	160	208	64	27	16	24	749
Gujar Khan	47	50	59	45	30	58	185	227	83	40	14	26	864
Pindi Gheb	26	30	47	33	23	27	121	73	43	12	8	17	459
Talagang	30	41	75	53	27	8	46	57	20	10	15	22	404
Khewra	58	74	123	135	74	15	26	25	24	29	32	45	662
Jhelum	42	45	55	36	29	50	232	226	85	18	12	23	853

Monthly Average (1984-2005)													
Station	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
Rawalpindi	47	87	83	45	26	67	267	323	99	33	12	40	1124
Murree	33	48	125	112	67	108	291	261	125	78	34	27	1309
Fateh Jang	36	69	67	44	26	44	184	203	76	29	9	25	812
Gujar Khan	35	57	58	36	27	65	213	203	74	23	5	24	745
Pindi Gheb/ Makhad	43	50	70	53	36	34	111	124	48	19	12	22	627
Talagang	44	49	69	23	30	45	122	113	57	24	4	26	606
Khewra	40	58	41	40	23	25	155	144	72	19	11	8	520
Jhelum	39	60	58	36	24	46	237	232	72	23	12	32	829

Monthly Rainfall of Stations in Pothwar

1954-83

MONTHLY RAINFALL AT GUJAR KHAN STATION (1954-83) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1954	119	93	28	8	12	9	116	136	91	57	2	8	679
1955	12	1	42	20	25	7	96	189	125	8	0	13	538
1956	25	53	63	10	0	84	187	235	54	13	0	5	729
1957	99	25	65	74	43	35	23	176	19	687	38	59	724
1958	6	5	68	10	3	9	183	134	94	5	9	82	608
1959	69	63	32	19	53	15	240	173	200	34	65	19	982
1960	62	0	64	28	3	5	145	145	56	8	0	27	543
1961	133	32	33	97	15	10	198	234	223	9	5	2	991
1962	11	37	42	19	19	60	105	179	27	0	30	37	566
1963	0	42	54	48	31	3	118	229	102	5	23	29	684
1964	89	14	13	31	18	10	332	144	123	0	13	11	798
1965	57	94	58	164	126	9	77	111	20	6	19	3	745
1966	0	135	64	39	33	159	150	207	54	38	0	0	879
1967	0	28	164	54	3	21	210	338	9	19	2	192	1040
1968	60	53	59	13	22	12	198	444	5	4	28	10	908
1969	3	56	45	52	59	6	105	112	59	29	2	0	528
1970	36	93	38	4	14	32	146	327	134	17	3	6	850
1971	2	46	8	51	38	156	219	315	54	6	5	3	903
1972	33	29	57	32	19	523	79	160	58	32	27	50	628
1973	53	70	54	13	43	70	287	288	127	19	0	36	1060
1974	28	36	14	21	13	67	194	154	36	0	0	29	592
1975	17	38	53	11	32	41	141	127	119	0	0	1	580
1976	83	148	84	46	2	24	261	315	144	29	0	1	1137
1977	51	11	9	39	43	102	440	182	27	14	17	15	950
1978	5	23	71	16	10	100	184	354	122	45	50	3	983
1979	29	56	98	3	35	44	180	153	80	26	19	103	733
1980	66	67	90	11	17	57	221	135	62	26	10	11	773
1981	114	52	126	94	78	14	413	241	93	7	4	0	1236
1982	53	62	123	136	71	14	113	446	29	18	59	17	1141
1983	94	37	57	189	19	35	184	415	137	53	2	0	1222
MEAN	47	50	59	45	30	58	185	227	83	40	14	26	824

MONTHLY RAINFALL AT RAWALPINDI STATION (1954-83) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1954	167	131	39	11	17	13	163	190	128	80	3	12	954
1955	16	1	59	28	35	9	134	265	176	12	0	19	754
1956	35	74	88	14	0	118	262	330	76	18	0	8	10236
1957	139	35	91	104	61	49	33	248	27	95	54	83	1019
1958	9	7	95	14	4	12	257	188	132	7	13	115	853
1959	97	89	45	26	75	22	336	243	281	48	91	26	1379
1960	87	0	90	39	4	7	204	203	79	11	0	37	761
1961	145	44	21	125	13	26	247	155	280	39	44	9	1148
1962	14	53	69	26	24	52	199	422	78	5	27	82	1051
1963	0	43	74	58	52	9	221	336	93	0	47	44	977
1964	143	14	21	44	46	25	264	92	47	0	2	13	711
1965	39	93	91	210	115	21	111	119	14	11	26	11	861
1966	0	165	80	53	61	102	164	194	88	39	0	14	960
1967	0	67	135	39	23	19	262	343	57	20	4	152	1121
1968	69	82	64	37	50	14	250	402	21	37	46	44	1116
1969	3	63	54	35	56	15	85	274	50	96	6	0	737
1970	72	80	79	12	16	38	189	325	172	25	1	8	1017
1971	22	57	11	79	27	239	170	390	76	1	12	8	1092
1972	73	48	108	68	19	52	39	82	114	74	19	73	769
1973	63	80	76	25	52	111	370	403	94	14	4	19	1311
1974	132	21	36	16	27	100	478	210	57	0	0	33	991
1975	39	59	64	43	33	18	236	391	154	0	0	6	1043
1976	116	208	117	65	3	33	367	443	203	40	0	1	1596
1977	72	15	13	55	61	143	618	254	38	19	23	21	1332
1978	6	32	100	23	14	140	259	497	172	63	70	4	1380
1979	65	102	147	14	41	29	119	231	109	17	36	23	933
1980	93	93	126	16	24	80	310	190	86	37	15	16	1086
1981	160	73	177	132	110	19	580	338	131	10	5	0	1735
1982	74	87	173	191	99	19	159	625	41	26	83	24	1601
1983	131	52	81	256	26	49	258	582	193	74	3	0	1714
MEAN	69	66	81	62	40	53	245	299	109	31	21	30	1408

MONTHLY RAINFALL AT JHELUM STATION (1954-83) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL
1954	90	78	15	3	17	23	79	91	329	106	3	0	834
1955	11	1	83	29	18	3	80	374	101	43	0	22	765
1956	29	15	85	31	0	56	309	182	58	21	0	1	787
1957	132	10	57	56	18	32	55	334	4	39	42	67	846
1958	0	2	39	10	8	18	256	100	162	1	0	90	686
1959	85	104	21	20	26	25	487	318	107	84	87	29	1393
1960	16	1	58	23	11	7	501	235	19	0	0	26	897
1961	102	42	36	100	19	16	323	87	193	32	24	3	977
1962	9	88	21	31	15	80	129	243	98	0	28	55	797
1963	0	28	65	52	46	29	97	203	193	3	40	20	778
1964	78	8	21	46	36	17	340	221	70	0	0	31	868
1965	37	59	31	66	82	9	211	92	8	54	10	3	662
1966	0	117	18	22	19	114	198	175	79	12	1	18	773
1967	0	34	77	39	17	18	128	228	13	15	8	120	697
1968	54	53	84	19	14	10	14	188	0	12	20	14	482
1969	14	36	35	70	79	4	199	189	68	6	1	0	701
1970	42	69	28	15	20	80	158	184	178	0	0	1	775
1971	5	54	4	24	29	121	181	175	15	2	11	1	622
1972	40	25	29	14	8	79	120	178	68	7	12	45	625
1973	36	34	30	5	48	23	405	293	66	5	0	38	983
1974	59	21	16	5	5	53	164	160	29	0	0	26	538
1975	14	53	34	10	41	149	332	352	252	0	0	0	1239
1976	40	89	56	25	15	31	164	546	67	10	0	0	1043
1977	60	1	1	60	38	146	352	146	8	13	3	14	842
1978	26	41	127	18	6	76	421	331	109	4	7	2	168
1979	25	110	89	0	18	66	294	223	80	4	12	17	938
1980	46	20	84	15	29	120	277	154	134	19	28	30	956
1981	118	55	114	4	49	13	292	169	16	3	3	0	836
1982	59	50	261	114	43	15	161	310	8	11	18	18	1068
1983	43	56	24	144	89	54	235	307	29	26	0	0	1007
MEAN	42	45	55	36	29	50	232	226	85	18	12	23	819

MONTHLY RAINFALL AT MURREE STATION (1954-83) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1954	259	221	153	48	61	57	337	258	241	112	17	6	1772
1955	36	7	145	54	138	76	409	841	123	44	0	66	1939
1956	84	36	236	93	1	188	617	443	82	127	1	79	1987
1957	243	44	214	258	130	73	200	273	78	230	155	85	1983
1958	29	26	153	67	48	18	322	519	133	69	7	243	1634
1959	94	162	124	109	173	123	558	254	300	71	104	46	2118
1960	112	7	183	81	45	37	431	264	120	12	7	48	1347
1961	151	116	72	270	79	92	308	335	302	97	82	26	1930
1962	22	106	142	120	83	89	301	250	164	15	49	58	1399
1963	0	115	235	138	80	82	297	284	180	3	66	44	1524
1964	255	72	70	156	71	72	401	269	269		7	113	1755
1965	51	207	151	389	209	72	356	286	32	63	44	18	1878
1966	0	213	166	174	96	119	277	316	209	168	0	47	1785
1967	6	207	229	181	114	44	277	309	173	56	27	110	1733
1968	212	126	120	73	97	100	350	332	24	78	36	80	1628
1969	43	103	114	117	111	55	220	204	100	193	24	0	1284
1970	120	119	164	51	25	105	263	417	314	48	0	21	1647
1971	0	148	33	180	36	519	215	275	23	10	25	25	1489
1972	0	0	0	0	0	0	163	281	223	80	35	125	907
1973	204	139	244	75	101	108	385	388	96	57	1	44	1842
1974	138	249	22	49	79	228	350	151	68	1	0	192	1527
1975	62	175	118	113	75	151	399	444	100		15	17	1669
1976	265	345	176	128	55	55	405	459	221	102	0	14	2225
1977	257	60	16	209	161	201	523	262	221	255	57	66	2288
1978	275	139	170	64	52	219	567	409	286	10	90	10	2285
1979	156	109	227	60	122	84	249	310	147	35	104	44	1647
1980	135	170	212	24	24	319	351	282	146	47	12	47	1769
1981	240	135	310	135	197	96	0.456	113	130	40	3	0	1855
1982	241	151	280	208	128	84	206	337	19	61	83	77	1875
1983	311	65	180	216	88	62	278	345	82	57	3	8	1696
MEAN	133	126	155	128	89	118	334	330	154	71	35	59	1747

MONTHLY RAINFALL AT FATEH JANG STATION (1954-83) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1954	106	76	38	0	19	0	68	197	17	52	0	0	573
1955	0	0	80	20	64	0	38	209	70	47	0	6	534
1956	20	26	119	20	11	51	235	328	13	84	0	3	910
1957	88	25	22	100	39	9	25	144	18	106	42	85	703
1958	0	3	41	19	16	10	144	153	82	27	0	166	661
1959	153	63	36	36	37	2	366	0	111	37	137	25	1003
1960	0	0	88	28	4	0	0	136	0	0	0	30	286
1961	0	0	0	73	33	57	0	0	156	16	0	6	341
1962	12	0	44	25	0	37	122	233	50	17	14	53	607
1963	0	30	51	40	36	6	153	233	64	0	33	30	676
1964	99	10	14	30	32	17	183	64	33	0	1	9	492
1965	27	64	63	145	80	14	77	82	9	8	18	7	594
1966	0	114	56	37	42	70	114	134	61	27	0	10	665
1967	0	46	93	27	16	13	181	237	39	14	3	106	775
1968	48	56	45	25	34	10	173	278	14	26	32	31	772
1969	2	44	38	24	39	10	59	190	35	66	4	0	511
1970	50	55	54	8	11	26	131	225	119	17	1	6	703
1971	15	39	8	55	19	165	118	270	52	1	8	6	756
1972	51	33	75	47	13	36	27	56	79	51	13	51	532
1973	44	56	52	17	36	77	256	279	65	10	2	13	907
1974	9	15	25	11	19	69	331	145	39	0	0	23	686
1975	27	41	44	30	23	12	163	271	106	0	0	4	721
1976	80	144	81	45	2	23	254	306	140	28	0	1	1104
1977	50	11	9	38	42	99	428	176	26	13	16	14	922
1978	4	22	69	16	10	97	179	344	119	43	49	3	955
1979	45	71	102	10	28	20	82	160	76	12	25	16	647
1980	64	65	87	11	16	55	215	313	60	25	10	11	750
1981	111	51	122	91	76	13	402	234	91	7	3	0	1201
1982	51	60	120	132	69	13	110	433	28	18	58	17	1109
1983	91	36	56	183	18	34	179	403	134	51	2	0	1187
MEAN	41	42	58	45	29	35	160	208	64	27	16	24	743

MONTHLY RAINFALL AT KHEWRA STATION (1954-83) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL
1954	238	191	152	140	31	30	104	43	26	52	9	15	1031
1955	18	13	122	62	99	21	69	10	17	14	7	26	478
1956	49	211	190	188	9	61	17	42	26	55	58	34	940
1957	115	62	179	169	75	32	15	29	7	71	100	83	937
1958	78	28	121	175	68	19	2	108	23	40	67	163	892
1959	151	108	130	145	200	2	27	2	20	7	109	172	1073
1960	65	62	204	221	56	21	11	14	77	19	29	31	810
1961	82	42	58	193	14	33	22	31	6	48	37	5	571
1962	13	32	54	108	82	21	55	20	35	22	56	33	531
1963	2	17	161	114	203	9	20	47	20	5	33	33	664
1964	69	105	65	223	50	13	6	5	25	36	35	68	700
1965	55	66	156	268	171	3	40	16	23	20	36	55	909
1966	1	94	326	156	12	0	4	23	41	20	0	2	679
1967	12	72	170	191	110	16	0	2	21	43	1	139	777
1968	27	42	119	209	109	2	13	40	0	46	38	83	728
1969	51	56	76	134	48	15	25	10	19	67	19	0	520
1970	42	19	100	69	26	13	27	9	64	45	0	50	464
1971	3	68	44	92	9	12	28	1	13	16	1	13	300
1972	68	104	160	115	161	36	57	18	64	39	33	16	951
1973	65	79	111	133	22	1	26	6	36	51	17	26	573
1974	64	143	15	133	87	11	30	69	29	3	0	32	586
1975	36	65	109	198	116	3	2	53	10	19	17	35	663
1976	37	117	101	69	28	9	1	34	26	6	8	12	448
1977	162	14	24	66	71	4	6	8	23	15	25	20	438
1978	46	37	191	79	39	11	73	8	0	37	36	8	565
1979	45	136	131	156	109	4	1	60	2	3	41	20	708
1980	42	73	117	56	64	8	11	13	36	37	22	55	544
1981	39	90	123	94	85	9	72	12	11	18	11	10	574
1982	29	74	39	46	57	6	24	4	14	7	99	89	488
1983	35	14	150	45	14	34	6	25	15	14	7	32	391
MEAM	58	74	123	135	74	15	26	25	24	29	32	45	663

MONTHLY RAINFALL AT TALAGANG STATION (1954-83) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1954	113	91	41	13	6	4	3	0	5	15	9	0	300
1955	1	2	26	2	24	0	6	108	2	9	4	1	185
1956	1	24	122	42	0	46	213	27	30	29	0	1	535
1957	50	15	99	130	22	0	39	7	5	71	44	34	516
1958	19	5	45	16	0	7	24	5	11	1	1	97	231
1959	93	78	42	57	47	5	33	81	75	3	112	22	678
1960	13	5	97	97	15	1	31	54	2	0	0	44	359
1961	90	31	16	90	2	19	47	78	46	40	26	0	485
1962	16	36	60	12	23	1	3	39	17	2	5	53	267
1963	0	25	116	55	87	12	1	3	4	2	32	42	379
1964	40	19	41	25	6	8	102	25	32	5	2	40	345
1965	21	44	28	158	120	10	90	2	0	1	15	11	500
1966	0	74	116	103	7	0	14	6	5	17	0	0	342
1967	0	47	213	45	34	0	16	35	54	19	9	145	567
1968	58	37	49	38	33	3	16	69	1	15	19	25	363
1969	0	56	47	45	59	0	79	9	14	23	16	0	348
1970	24	25	38	19	0	12	36	84	58	0	0	10	306
1971	2	48	38	114	14	6	18	73	39	6	0	6	364
1972	38	65	51	57	38	11	18	10	13	1	12	50	364
1973	4	68	92	17	62	0	16	41	62	3	0	9	374
1974	5	47	9	32	8	0	20	13	25	0	0	34	193
1975	1	49	93	42	63	3	71	105	2	0	0	6	435
1976	13	83	82	49	3	19	41	280	20	14	0	1	605
1977	62	12	0	75	20	0	208	9	36	5	23	8	458
1978	16	15	223	26	1	11	88	74	8	4	31	0	498
1979	81	83	53	9	36	12	15	95	0	0	18	1	403
1980	28	70	96	8	14	33	30	50	5	8	8	2	372
1981	34	29	150	28	35	2	24	85	0	9	0	0	396
1982	30	13	96	20	4	1	2	10	0	1	51	14	242
1983	39	39	81	179	39	14	62	218	25	10	10	1	717
MEAN	30	41	75	53	27	8	46	57	20	10	15	22	404

Monthly Rainfall of Stations in Pothwar

1984-2005

MONTHLY RAINFALL AT RAWALPINDI STATION (1984-2005) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1984	0	80	84	57	0	61	30	493	32	0	1		837
1985	18	1	23	10	7	5	186	21	18	38	11	108	447
1986	12	149	115	66	35	92	86	173	73	58	30	46	935
1987	0	134	73	42	96	27	63	246	0	75	0	7	762
1988	17	23	153	9	9	98	450	282	126	31	0	72	1271
1989	67	11	72	13	5	57	365	370	28	4	2	51	1044
1990	41	105	160	53	0	29	240	436	168	21	8	178	1441
1991	4	107	104	117	17	89	252	264	217	3	4	17	1193
1992	100	91	119	31	37	15	257	305	258	9	35	8	1264
1993	36	30	141	22	45	78	153	211	94	6	15	0	830
1994	36	51	36	69	36	54. 8	597	638	56	30	1	93	1643
1995	29	72	76	59	29	15	486	332	8	45	25	31	1205
1996	82	122	130	47	32	145	299	328	72	60	3	6	1326
1997	39	20	84	172	46	65	195	496	158	96	18	29	1418
1998	36	239	88	106	19	32	360	345	79	18	0	0	1322
1999	83	36	81	2	22	33	232	334	145	10	35	0	1012
2000	129	71	18	3	11	37	207	381	129	0	0	14	999
2001	0	0	32	5	27	186	801	212	21	30	7	0	1320
2002	7	33	43	11	3	110	108	368	171	42	0	22	917
2003	39	176	83	21	23	100	312	267	258	3	17	45	1345
2004	141	51	0	91	16	92	116	399	6	97	37	83	1128
2005	72	359	120	3	21	33	83	210	53	61	13	31	1058
MEAN	47	87	83	45	26	67	267	323	99	33	12	40	1124

MONTHLY RAINFALL AT GUJAR KHAN STATION (1984-2005) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1984	0	55	79	34	4	79	243	498	77	0	23	11	1102
1985	24	5	12	39	32	30	197	87	63	28	7	66	589
1986													0
1987	4	103	51	6	60	23	101	149	36	72	0	1	605
1988	12	20	103	0	5	35	501	135	86	12	0	42	949
1989	35	0	54	22	39	42	203	278	39	3	5	36	756
1990	20	55	145	16	77	31	171	266	81	8	0	147	1015
1991	8	51	81	92	10	28	230	266	155	3	3	24	951
1992	148	92	93	34	34	68	102	0	0	0	0	0	572
1993	13	29	77	10	34	113	89	48	66	0	3	0	482
1994	20	26	34	115	30	80	600	285	15	40	0	87	1332
1995	23	42	81	34	7	58	386	86	16	41	21	7	802
1996	66	110	35	12	20	171	112	159	57	49	2	2	794
1997	30	11	82	169	29	61	57	507	128	117	14	19	1224
1998	18	214	44	83	30	20	185	182	85	25	0	0	886
1999	116	24	37	0	17	84	112	200	97	3	3	0	692
2000	65	43	20	6	28	39	59	192	124	5	6	11	599
2001	6	0	6	32	53	123	267	127	78	27	0	0	717
2002	4	17	24	3	25	81	91	214	129	20	0	18	626
2003	16	138	47	9	13	51	291	131	130	4	6	4	840
2004													0
2005	67	97	64	3	3	83	264	250	17	8	0	0	853
MEAN	35	57	58	36	27	65	213	203	74	23	5	24	745

MONTHLY RAINFALL AT MURREE STATION (1984-2005) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1984	0	0	157	135	72	196	298	478	107	0	36	15	1493
1985	112	3	72	80	44	33	426	383	195	66	17	50	1480
1986	20	0	73	108	77	158	328	462	101	112	131	8	1578
1987	0	40	197	98	225	127	139	315	108	185	0	0	1434
1988	1	27	273	27	9	138	697	292	176	575	0	41	2258
1989	0	0	206	91	50	58	347	230	56	67	28	24	1158
1990	20	98	232	174	36	93	441	424	143	1	0	82	1744
1991	52	135	168	352	100	98	229	174	171	10	13	9	1512
1992	243	7	298	103	123	26	310	277	316	19	46	18	1786
1993	44	82	145	57	44	302	358	116	89	24	38	0	1301
1994	0	0	93	148	77	45	453	225	42	72	0	197	1354
1995	58	91	97	76	49	16	416	187	49	25	13	33	1109
1996	79	7	140	61	87	212	165	645	152	220	23	0	1792
1997	41	5	196	352	197	85	376	345	277	116	66	19	2075
1998	0	208	23	294	37	27	233	0	102	8	0	0	931
1999	0	25	49	0	20	38	225	314	193	41	117	0	1022
2000	0	0	0	0	0	131	213	69	0	0	0	0	412
2001	0	18	63	60	14	99	106	53	121	10	77	0	621
2002	5	19	69	19	15	388	143	303	37	0	0	39	1037
2003	34	267	122	134	38	35	97	169	113	0	17	10	1035
2004	22	23	0	84	112	21	151	200	94	158	133	41	1039
2005	0	0	85	18	51	42	253	85	104	0	0	0	638
MEAN	33	48	125	112	67	108	291	261	125	78	34	27	1309

MONTHLY RAINFALL AT JHELUM STATION (1984-2005) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL
1984	0	49	22	7	0	24	284	156	89	11	19	11	672
1985	9	6	0	38	52	19	176	54	0	31	3	81	470
1986	9	92	89	45	18	51	178	263	24	43	30	59	899
1987	6	88	57	21	71	13	105	244	21	22	0	0	647
1988	24	36	69	2	0	40	503	155	68	9	8	79	992
1989	42	9	42	26	14	16	238	178	56	0	4	40	665
1990	16	85	163	26	39	21	213	205	236	0	2	186	1192
1991	9	137	46	117	36	31	179	280	121	3	8	26	992
1992	92	61	262	24	44	22	127	282	155	12	51	4	1134
1993	36	48	84	32	6	86	192	63	115	0	0	0	662
1994	11	24	19	55	2	33	457	297	13	22	0	67	1000
1995	45	34	96	41	9	19	648	214	9	19	23	1	1157
1996	47	122	52	6	13	122	103	303	69	152	1	1	989
1997	34	13	34	111	23	55	320	533	67	17	35	52	1293
1998	7	125	24	55	30	25	252	304	56	63	0		941
1999	110	8	21	0	8	39	141	157	126	1	19	0	630
2000	59	46	8	2	45	103	211	292	74	0	2	1	840
2001													
2002	47	7	24	30	1	97	64	158	93	4	0	8	533
2003	34	172	43	16	8	82	226	245	88	10	26	11	962
2004	93	30	0	54	51	52	149	348	11	42	15	15	859
2005	80	66	57	57	29	12	210	149	20	32	0	0	712
MEAN	39	60	58	36	24	46	237	232	72	23	12	32	829

MONTHLY RAINFALL AT FATEH JANG STATION (1984-2005) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1984	1	44	81	48	4	46	97	325	80	10	18	24	779
1985	39	3	21	61	22	73	315	96	81	56	0	90	857
1986	10	103	80	69	30	45	167	167	40	52	32	23	818
1987	0	137	73	27	85	40	52	92	23	52	0	0	581
1988	23	24	180	10	5	26	174	126	49	76	0	52	745
1989	38	6	80	3	19	29	209	127	38	0	5	56	610
1990	54	55	117	47	0	45	212	327	204	24	0	108	1193
1991	12	83	103	120	49	13	171	244	200	5	34	22	1056
1992	98	95	76	28	48	18	186	270	0	23	13	14	869
1993	24	27	90	31	27	101	188	150	164	0	3	0	805
1994	30	43	25	77	44	14	271	204	37	54	0	42	841
1995	16	72	77	71	26	0	394	193	47	50	30	28	1004
1996	58	106	64	20	29	92	93	230	97	30	0	16	835
1997	25	13	44	136	58	37	134	375	184	75	18	10	1109
1998	12	217	56	77	20	50	141	275	47	18	0	0	913
1999	102	15	42	4	13	53	238	342	78	0	20	0	907
2000	72	49	19	4	7	23	92	136	115	0	0	23	538
2001	0	0	22	18	21	50	328	69	21	0	0	0	528
2002	5	35	41	20	11	3	3	263	3	0	0	1	386
2003	0	171	62	19	15	35	361	240	118	3	14	21	1060
2004	68	45	0	75	18	93	5	94	10	65	15	19	507
2005	96	168	115	5	27	75	226	127	42	46	5	0	932
MEAN	36	69	67	44	26	44	184	203	76	29	9	25	812

MONTHLY RAINFALL AT KHEWRA STATION (1984-2005) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL
1984													
1985													
1986													
1987	0	70	62	8	65	0	135	100	15	0	0	0	454
1988	15	15	149	6	7	12	190	171	35	4	3	49	655
1989													
1990	134	81	57	17	30	28	0	104	126	52	130	43	801
1991	128	311	35	35	13	2	115	109	21	2	0	5	774
1992	84	34	70	23	31	57	59	93	261	19	22	0	752
1993	15	24	36	0	8	12	459	65	257	0	0	0	875
1994	0	22	27	54	19	21	90	244	60	37	0	35	608
1995	0	0	0	35	31	16	168	244	8	26	0	9	536
1996	31	71	22	221	59	28	309	507	9	69	0	0	1325
1997	11	5	22	60	44	38	283	0	93	11	13	4	584
1998	21	267	71	188	32	95	434	222	90	53	0	0	1474
1999	134	17	100	0	31	0	295	186	165	50	23	0	1001
2000	103	57	8	43	6	35	103	48	88	13	0	4	507
2001	0	0	31	26	30	77	25	3	5	0	0	0	197
2002	2	7	4	0	4	8	14	162	33	2	0	2	238
2003	13	42	20	4	13	2	100	267	8	1	1	1	472
2004	0	0	0	0	0	0	0	0	16	0	0	0	16
2005	21	30	17	0	1	12	15	72	0	1	0	0	169
MEAN	40	58	41	40	23	25	155	144	72	19	11	8	520

MONTHLY RAINFALL AT TALAGANG STATION (1984-2005) - mm													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1984	0	0	81	15	0	23	162	229	96	0	25	0	631
1985	0	0	0	0	0	3	10	51	0	3	0	44	110
1986	15	45	46	12	25	40	138	74	21	23	8	7	453
1987	0	50	96	18	56	6	123	18	18	0	0	0	385
1988	56	10	85	13	0	40	125	230	5	18	0	29	611
1989	23	6	70	0	20	10	63	118	49	0	0	25	386
1990	10	45	54	18	0	8	33	96	66	5	0	122	456
1991	0	58	46	92	27	26	151	154	32	0	9	0	595
1992	22	6	62	4	14	6	27	91	67	0	5	0	306
1993	5	5	89	32	0	258	15	23	108	0	0	0	535
1994	54	61	36	101	28	0	320	0	54	148	0	171	974
1995	58	91	97	76	49	16	416	187	49	25	13	33	1109
1996	58	152	182	27	93	240	234	271	160	0	0	0	1419
1997	51	56	0	0	97	94	21	0	0	0	0	0	317
1998	72	26	0	0	60	60	418	474	243	261	0	0	1613
1999	296	0	273	0	123	81	123	113	20	0	25	93	1147
2000	22	25	87	0	20	0	0	83	28	0	0	0	266
2001	0	0	0	7	11	16	39	35	5	0	0	4	117
2002	0	24	0	0	0	7	10	21	29	0	0	9	100
2003	1	87	71	9	8	0	19	83	70	27	2	19	394
2004	141	51	0	91	20	19	77	102	22	17			541
2005	91	282	150	0	2	41	152	42	104	0	0	0	864
MEAN	44	49	69	23	30	45	122	113	57	24	4	26	606

MONTHLY RAINFALL AT PINDI GHEB/MAKHAD STATION (1984-2006)													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL
1984	3	52	81	74	12	55	104	261	114	32	29	74	892
1985	121	43	76	81	25	55	159	163	99	122	20	86	1051
1986	90	83	227	150	188	131	220	108	104	48	64	74	1486
1987	9	28	145	96	157	101	149	164	33	11	5	5	903
1988	121	71	226	107	27	6	117	56	34	0	0	34	798
1989	14	0	46	0	0	28	89	396	5	0	0	3	580
1990	1	6	86	30	0	0	58	168	0	3	0	7	360
1991	0	6	4	118	1	0	76	55	0	0	0	0	260
1992	7	5	61	43	13	26	77	61	17	0	0	0	310
1993	0	2	4	0	25	3	27	28	2	0	0	0	91
1994	0	1	26	31	0	0	12	44	40	0	0	3	158
1995	58	91	97	76	49	16	416	187	49	25	13	33	1109
1996	48	43	97	0	8	48	18	77	30	20	0	0	390
1997	18	17	15	144	65	0	118	116	0	87	25	33	637
1998	56	118	75	42	30	15	72	208	119	8	0	0	744
1999	90	28	18	23	48	36	84	53	33	0	53	0	466
2000	79	48	23	13	16	0	46	79	30	0	0	13	346
2001	0	4	25	41	33	58	206	130	60	30	0	0	587
2002	6	40	35	41	33	25	55	68	38	17	12	30	401
2003	19	123	23	18	19	61	115	66	53	0	23	39	560
2004	141	51	0	91	20	38	66	124	94	19	23	48	716
2005	91	282	150	0	30	41	152	107	104	0	0	0	958
MEAN	44	52	70	55	36	34	111	124	48	19	12	22	627

Annexure-III

Parameters for Curve Number (CN) Estimation

Table 1: Curve Number for Soil cover complexes *(SCS, 1972)*

LAND USE OR COVER	TREATMENT OR PRACTICE	HYDROLOGIC CONDITION	HYDROLOGIC SOIL GROUP A	B	C	D
Fallow	Straight row	—	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Contoured and terraced	Poor	66	74	80	82
	Contoured and terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Closed seed	Straight row	Poor	66	77	85	89
Legumes[a] or Rotation meadow	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Contoured and terraced	Poor	63	73	80	83
	Contoured and terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		—	59	74	82	86
Roads						
Dirt[b]		—	72	82	87	89
Hard surface[b]		—	74	84	90	92

Table 2: Curve Number for different antecedent conditions (*SCS, 1972*)

CN FOR AMC II	CORRESPONDING *CN*s AMC I	AMC III
100	100	100
95	87	98
90	78	96
85	70	94
80	63	91
75	57	88
70	51	85
65	45	82
60	40	78
55	35	74
50	31	70
45	26	65
40	22	60
35	18	55
30	15	50
25	12	43
20	9	37
15	6	30
10	4	22
5	2	13

AMC denotes antecedent moisture condition.

AMC I. Lowest runoff potential. Soils in the watershed are dry enough for satisfactory plowing or cultivation.

AMC II. The average condition.

AMC III. Highest runoff potential. Soils in the watershed are practically saturated from antecedent rains.

Annexure-IV

Average Annual Discharges of Major Rivers in Pothwar

Discharges of Soan River

(cusecs)

Year	Soan at Chirah	Soan at Rawalpindi	Soan at Dhok Pathan	Soan at Makhad
1960	0.00	18.51	-	81.92
1961	7.37	24.43	-	104.42
1962	2.67	13.44	-	31.35
1963	3.63	18.08	-	15.96
1964	4.51	22.56	44.50	46.80
1965	4.25	17.35	35.43	41.84
1966	3.63	19.56	33.73	28.83
1967	5.47	21.94	66.04	56.92
1968	4.08	19.95	50.45	54.88
1969	1.64	9.35	21.49	16.61
1970	0.08	21.29	61.51	10.86
1971	7.57	24.69	38.83	42.63
1972	3.29	9.21	13.92	50.91
1973	5.56	20.04	45.35	149.18
1974	2.44	13.35	20.69	101.90
1975	7.37	18.76	35.15	123.36
1976	11.51	41.10	82.20	287.90
1977	8.53	3.15	51.98	195.63
1978	10.86	11.42	71.23	322.90
1979	5.50	11.76	35.15	185.18
1980	0.00	0.00	0.00	238.80
1981	2.32	8.39	29.12	151.29
1982	7.72	27.98	49.63	157.61
1983	7.18	24.73	66.31	171.25
1984	5.87	24.22	54.63	227.86
1985	1.79	14.66	30.48	89.18
1986	8.67	19.13	40.16	149.65
1987	2.22	8.78	24.73	85.00
1988	11.59	35.19	61.28	134.81
1989	2.29	13.67	31.44	106.75
1990	7.49	32.74	67.01	109.47
1991	5.46	22.90	65.92	159.15

Year	Soan at Chirah	Soan at Rawalpindi	Soan at Dhok Pathan	Soan at Makhad
1992	12.46	34.37	68.63	161.53
1993	2.77	15.82	30.98	75.38
1994	13.22	51.43	94.81	183.03
1995	6.04	25.24	45.64	177.79
1996	2.61	23.35	44.20	96.34
1997	2.62	23.46	55.74	119.82
1998	2.66	29.82	54.10	103.55
1999	0.97	8.67	29.62	57.89
2000	1.64	12.01	32.50	57.02
2001	1.10	20.83	30.55	46.41
2002	3.12	13.64	19.08	37.77
2003	2.65	21.65	34.80	48.97
2004	1.52	8.45	24.17	39.69
2005	2.58	13.42	38.35	62.97