Impacts Evaluation of Chashma Right Bank Canal on the Water-Table of District Dera Ismail Khan, Pakistan

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Abstract: This paper analyses the impact evaluation of Chashma Right Bank Canal (CRBC) on the water-table of district D.I. Khan, Pakistan. The study area falls in the arid agro-ecological zone of Pakistan. In order to achieve objectives of the study, data were gathered from both primary and secondary sources. Primary data were obtained through a detailed field survey, where five sample villages were also selected by random means for micro-level analysis. Out of which four from CRBC command areas and one village from outside the command area. Data were also collected during focused group discussion with the farmers and elderly people to grasp the ex post impact of CRBC on water-table. In addition to this, pre-CRBC data were obtained from WAPDA. The analysis reveals that in the study area water-table varies from area to area. A large tract of saline groundwater is available in the western section, whereas the eastern section has good quality of freshwater aquifers. After the construction of CRBC, there has been a gradual rise in water-table due to intensive irrigation, introduction of water loving crops, high cropping intensity and unlined irrigation network. The analysis further reveals that in certain areas, the rise in water-table is very alarming. Such threatening situation may encourage waterlogging, soil salinization that may halt agricultural productivity.

Keywords: Impact evaluation, CRBC, water-table, saline water, cropping intensity.

1. INTRODUCTION

This paper attempts to analyze the impacts of Chashma Right Bank Canal (CRBC) on the water-table of Dera Ismail Khan (D.I. Khan) district, Pakistan. It is pertinent that water is abundant natural resources on the earth [1-2]. However, only 1% of it is available for human use [3]. It has been estimated that since 1970, the global demand of water for industrial, domestic and agricultural purposes have increased at the rate of 2.4 % per year [4]. Despite the rising demand of water, the per capita availability of fresh water has been reduced by 40-60% in several Asian countries during 1955 to 1990 [5]. Cultivated area is a major user of fresh water and consumes 71% of the water use [6].

Scientific literature reveals that irrigation is the artificial supply of water to crops [7-8]. Globally, it is irrigated areas, which significantly contributes to the agricultural output and food supply [9-10]. Currently, irrigated agriculture provides about 40% of the world's food, from only 20% of its cultivated area [2, 5, 11] found that in Asia, over 90% of the total irrigation water is utilized by the rice crop. Contrary to this, the unwise utilization of irrigation has generated off-farm impacts including waterlogging, soil salinity and water pollution [12].

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Increasing expansion in the irrigated area is mainly due to large-scale irrigation projects [13-14]. Irrigation projects are usually associated with its positive impacts, while unwise irrigation practices are associated with adverse impacts, which may eventually curtail the sustainability of irrigation projects [15]. In a number of countries, irrigated agriculture has resulted environmental degradation in the form of waterlogging and salinization. Waterlogging is caused by the over and uncontrolled irrigation, seepage and percolation from field and channels, impervious obstruction, inadequate natural and surface drainage, excessive rain, irregular and flat topography [13, 16]. The percolated water raises the underground water-table and causes waterlogging. Globally, approximately 10% of the total irrigated area is suffered from waterlogging. This has dropped 20% agricultural productivity in many cases [6]. In Pakistan, waterlogging is the product of canal irrigation [7]. Globally, about 1.5 M ha of cultivated land is lost every year due to waterlogging ad salinity [16].

In Pakistan, with the advent of canal irrigation, there has been major challenge of waterlogging that retard agricultural growth [1, 17]. In Pakistan, the rate of change in irrigation intensity is quite high in district D.I. Khan as compared to rest of districts in Khyber Pakhtunkhwa and Pakistan. This change is attributed to the inception of CRBC in district D.I. Khan. Work on the CRBC was started in 1984 and completed in 2003. The CRBC was completed in three phases. Phase I, II

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and part of III falls in district D.I. Khan (Khyber Pakhtunkhwa) and rest of stage III in D.G. Khan District (Punjab) and therefore accorded high priority (Figure **1**). The CRBC commands only left bank area as the slope is from west to east. The CRBC aims to increase agricultural productivity, improve farm income and provide employment to the expanding rural labour. It is 272Km long canal, spread over the two provinces including 170Km in KP and the rest 102Km in Punjab. CRBC commands 250,000 ha, out of which 61% falls in D.I. Khan district and rest 39% in D.G. Khan District.

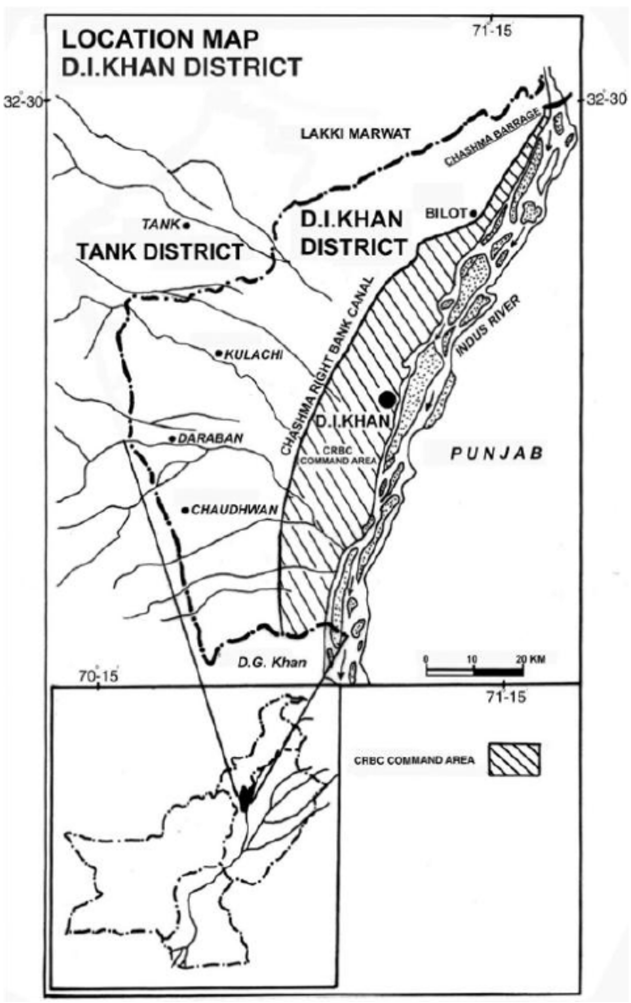

Figure 1: Location of D.I. Khan and CRBC.

2. METHODS AND MATERIAL

2.1. The Study Area

District D.I. Khan is a vast plain bounded by mountains on two sides [18]. It consists of low hills that ranges in height from 750 m to 1,000 m above sea level. In 1998, the total population of district D.I. Khan was 853,000, which grew during 1981-98 at an average annual rate of 3.26% [19-20]. Since the inception of Pakistan, the population of D.I. Khan is growing faster than the national average. Physically, D.I. Khan district can be divided into several broad regions [20]. Active floodplain forms a narrow strip of about 1 to 8 km wide on the right bank of river Indus. Rolling sand plain is found at the foot of the Marwat-Bhittinni range [21]. Hilly sand plain occurs at the foot of the Sur Ghar hills and is separated from the piedmont plain by the Paharpur canal [22]. Piedmont plain is rather a large landform unit and occurs in the central parts of the district, between the alluvial fans and the Indus floodplain.

In D.I. Khan, summer is long hot, whereas winter remains short and cold. The mean maximum and minimum temperature recorded in June is 42°C and 27°C, respectively [3]. The temperature begins to rise from March to June and then falls gradually. During summer, the mean daily maximum temperature is above 36°C. winter is short and January is the coldest month with mean minimum temperature of 4°C. In D.I. Khan district, average annual rainfall is about 300 mm, which are mainly received in two well-marked seasons; approximately 45% in monsoon, while the western disturbances are responsible for 30% of the annual rainfall mainly received in winter and spring. The high temperature, low rainfall and its poor seasonal distributions is considered as a natural barrier in the promotion of agriculture sector.

The soil of D.I. Khan has been formed from mixed calcareous alluvium and local outwash plain derived from the Suleiman and Marwat ranges. The floods usually bring clay and fine silt, and deposited the same in various tracts of D.I. Khan areas [23]. The hydro-geological results assessments reveal that the central part of the piedmont plain consists of sand layers with alternate clay deposit. The floodplain deposits along the Indus River consist of thick sand formation and have good aquifers. The flow of groundwater in the piedmont plain is from west to south-east. In D.I. Khan, both fresh and saline groundwater is reported. Major part of the area has been found to contain saline water [23]. The groundwater table in most parts is less than 20m and in the piedmont it varies from 20m to 100m. In the study area, groundwater is recharged from the mountainous streams, CRBC and Indus river.

2.2. Methods of Data Collection and Analysis

To achieve the study objectives, extensive primary and secondary data sources were consulted. Data were obtained from both inside and outside the CRBC command area. Several field visits were arranged to get clear pictures of both positive and negative impact of CRBC on land utilization, irrigated land and water-table. For collection of primary data, three types of questionnaires were designed: individual household, Focus Group Discussions and questionnaire for the related line departments. For the government line departments, questionnaires were filled-up by interviewing officials of the related departments.

In D.I. Khan district, there were a total of 384 mouza (smallest revenue unit) in 1998. However, for detailed and intensive study, out of total 194 CRBC command villages, four were randomly selected for micro-level analysis namely: Gomal, Jarra, Chera and Buchari, which make 2.4% of the CRBC command villages. Likewise, village Khudaka was also randomly selected from off the CRBC command villages. The four sample villages were randomly selected from the three stages of CRBC .i.e. from stage I village Jarra (middle reach), stage II Gomal (head reach) and stage III Buchari and Chera (tail reach). Likewise, for each and every sample village, a set of questionnaires were filled-up during Focused Group Discussions to grasp the pre and post CRBC water-table. Group discussions were made with the farmers, member of the local organizations and community leaders that enabled to cross check the individual questionnaire data.

The secondary data were collected from the office of Chashma Right Bank Irrigation Project, D.I. Khan; Ministry of Water and Power, Islamabad; Directorate of Hydrology, Lahore; WAPDA, WAPDA house, Lahore; Salinity Control And Reclamation Project (SCARP), D.I. Khan; Revenue and estate Department, D.I. Khan; Pakistan Meteorology Department, Peshawar; Population Census Organization of Pakistan, Islamabad; Bureau of Statistics, Peshawar; Director General Agriculture, Peshawar; Department of Revenue and Estate, Peshawar. The collected were analysed in MS Excel and GIS. Finally, the collected data and information were interpreted in the light of existing socio-economic and physio-ecological environment of the study area.

3. ANALYSIS, RESULTS AND DISCUSSION

3.1. Impacts Evaluation of CRBC on Irrigation

In D.I. Khan district, cultivated area is irrigated by canal, inundation, lift and Rod Kohi. Rod Kohi is a form of hill torrent irrigation governed over a century old system called *Rewajat* [3, 24]. In district D.I. Khan, Indus is a major source of water for irrigation and due to gentle slope it is braided into numerous small and large distributaries. In Indus, the discharge remains low in winter, but begins to rise in April and gradually inundates most of the riverine tract from July to September.

In the study region, canal-irrigation is reported from a narrow belt along the Indus river in the east. The construction of three stages of CRBC has provided additional canal water. The piedmont plain is traversed by a number of hill torrents. The most important of these are Paniala, Tikwara, HauzKhad, Khad Buds, Luni, KhauraKhad and Ramak. Hill torrent or Rod Kohi irrigation is practised in western part of the district. It is an indigenous system of water supply for agricultural land and is designed to function under the prevailing adverse dry conditions [18]. The perennial streams are known as *Zam* mainly reported from the western and north-western parts of the district. The most important perennial streams are the Gomal, Tank, Zarkani, Daraban and Chaudhwanzam. This type of irrigation is potentially better than Rod Kohi because of more reliable and systematic distribution of water. In the Indus floodplain, summer inundation is the major source of groundwater recharge. The volume, time and duration of floods are uncertain and vary from place to place. Narrow eastern fringes of *daman* and most of the active floodplain have good quality of groundwater that is suitable for lift irrigation.

Prior to CRBC, a small share of command area was irrigated by Paharpur canal, Zam, Rod Kohi, inundation and lift irrigation system. After inception of CRBC, a gradual increase in the irrigated area recorded after 1969-70. The statistical analysis reveals that pre CBRC (1969-70), total irrigated land was 52,023 ha as compared to post CRBC 145,798 ha, during 2002-03 (Figure **2**). After CRBC a net positive change of 10.77% of the total reported area has been recorded in the irrigated area. The increase in the irrigated area is attributed to the CRBC. Therefore, in the CRBC command area, a considerable rise in the water-table has been noted (Table **1**). The analysis further reveals that pre CRBC in 1969-70, area under lift irrigation was 24,656 ha, which was subsequently decreased to 18,300 ha in 2002-2003. The overall decrease in the area under lift irrigation is mainly because the same land was brought under the command of CRBC (Figure **2**). Worldwide, lift irrigation is also applied as one of the anti-waterlogging strategy. After commissioning of CRBC, the area under lift irrigation brought under canal irrigation. As a result, the rapid recharge of groundwater was recorded.

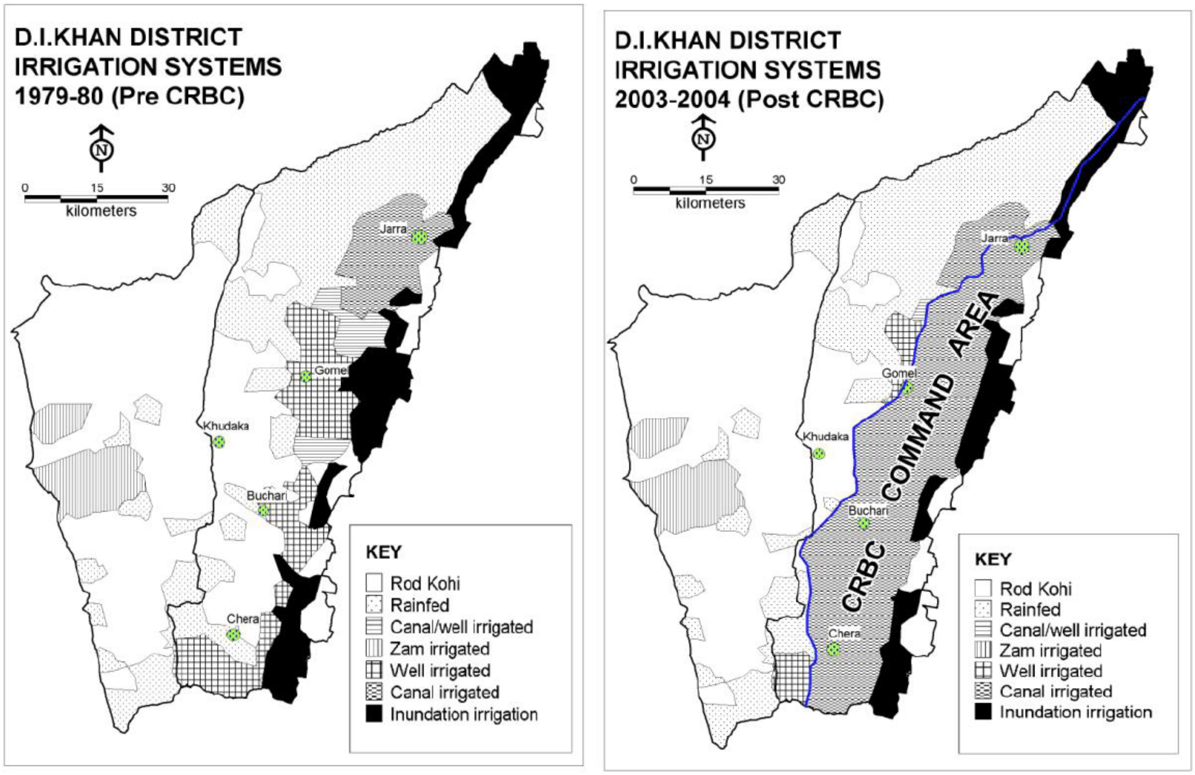

Figure 2: Pre and post CRBC change in irrigation pattern after *GoP 1969; Said 1971; GoP 1999; JICA 1993; WAPDA 1985; 2002.*

3.2. Impacts Evaluation of CRBC on Land Use

In district D.I. Khan, land utilization has been classified into uncultivated, cultivated and cultivable waste. In the study area, cultivable waste is the major land use category followed by the cultivated area. The analysis reveals that in district D.I. Khan out of the total reported area (730,575 ha), 232,036 ha was cultivatedin 1969-70, which after the inception of CRBC enhanced to 236,371 ha in census year 2003-2004. Furthermore, in the study area, large tract is under built environment and hence not suitable for cultivation. Prior to the commissioning of CRBC (1969-70), the uncultivated area was 132,408 ha, which after the inception of CRBC increased to 132,487 ha in 2003-04. The analysis further indicates that there has been gradual reduction in area under cultivable waste especially after the inception of CRBC. However, prior to commissioning of CRBC, area under cultivable waste was 366,132 ha in 1969-70, which decreased to 357,809 ha in 2003-04.

3.3. Impacts Evaluation of CRBC on Water-Table

Initially, CRBC was designed with a fixed allowance of 0.60 L/s/ha, which was required to meet crop requirements for an estimated 143% cropping intensity [25]. Similarly, to increase agricultural production, the CRBC was designed to use crop-based irrigation. This discussion provides feedback to analyse various factors leading to the problems of rising water-table. In certain part of CRBC command area, groundwater is saline and even unfit for domestic supply and irrigation. The ground water-table in most parts of the floodplain is generally less than 20 metres, whereas in the piedmont plain it ranges from 20 metres to over 100 metres. Large quantity of fresh groundwater is also available, but it is commonly overlain by saline water. In the saline water belt, the presence of fresh groundwater could not be determined, to a depth of 283 metres in the piedmont plain[25]. However, the water quality improves between 217 to 296 metres depth and the aquifers appear to contain fresh groundwater.

In D.I. Khan, groundwater is progressively deeper as one move from the Indus river towards the piedmont (East to west). According to FGDs survey, both inside and outside the CRBC command area, water-table is steadily inclining. Farmers in a given vicinity experienced localized changes in the water-table, but outside the command area, majority of the respondents replied that no changes in water-table occurred. According to individual household survey, seepage and percolation is a significant problem all along the unlined watercourses. The analysis found that the problem of waterlogging is severe in certain parts of stage I, where water-table is close to the surface. On the average, the water-table in stage I and II is 3.3 and 10 meters below surface, respectively.

The field observation together with the FGDs and officials of the line departments indicates that the unwise utilization of water, intensive irrigation and trend towards the water loving crops has significantly inclined the water-table in the CRBC command area. The analysis of sample villages reveals that the average height of sample village Jarra is 191 meters above mean sea level (Figure **3**; Table **1**). As one proceeds downstream up to Chera, the altitude gradually decreases. The average height of Chera is 179 meters above mean sea level. As far as Khudaka is concerned, its elevation is 190 meters as it is located outside the CRBC command area.

After the inception of CRBC, in Jarra large area was severely affected by waterlogging and salinity. The twin problem continued to affect the land for almost eight years. The problem was mitigated when watercourses lined and anti-waterlogging drain was dugout, under the name of Paharpur SCARP. This project was launched by water wing, WAPDA during 1989-90. The Table **1** reveals that in Jarra prior to CRBC, the ground water-table was -14 meters below the surface (1986), which inclined to -5 meters after CRBC in 2005 (Figure **3**; Table **1**). The analysis reveals that there is a significant difference in land levelling between stage I, II and III. The fields are more levelled at the tail end in stage I and II. However, stage III has extensive unlevelled land at the head and tail reaches due to which a lot of water is wasted and consequently added to the groundwater.

According to FGDs and individual household survey together with the secondary data reveals that in Gomal, the water-table was on average -20 meters below the surface during 1988 (Pre CRBC), which inclined to -10.5 meters in 2005 (post CRBC) indicating a rising trend of 0.53 meters per year (Figure **3**; Table **1**). If this increasing trend of water-table continues, it will soon adversely affect the cultivated land and in effect, the land will become unfit for cultivation. According to field observation together with the focused group discussion found that intensive irrigation, unlevelled land and trend towards crops that require plenty of water are the dominant contributing factors for inclining water-table in Gomal.

Similarly, in Buchari, the water-table was -61 meters prior to CRBC during 1991, which inclined to -44 meters below the surface during 2005 (Figure **3**; Table **1**). It means that the inclining rate is 1.13 meter per year. This is very rapid pace. If, this trend is compared with that of Chera, it is relatively slow increase. This increase is mainly due to the introduction of water loving crops, unlevelled fields and unwise irrigation practice as a result of CRBC.

In Chera, the water-table pre CBRC was -21 meters below the surface in 2000, which after 5 years of CRBC commissioning, the water-table rose to -9 meters

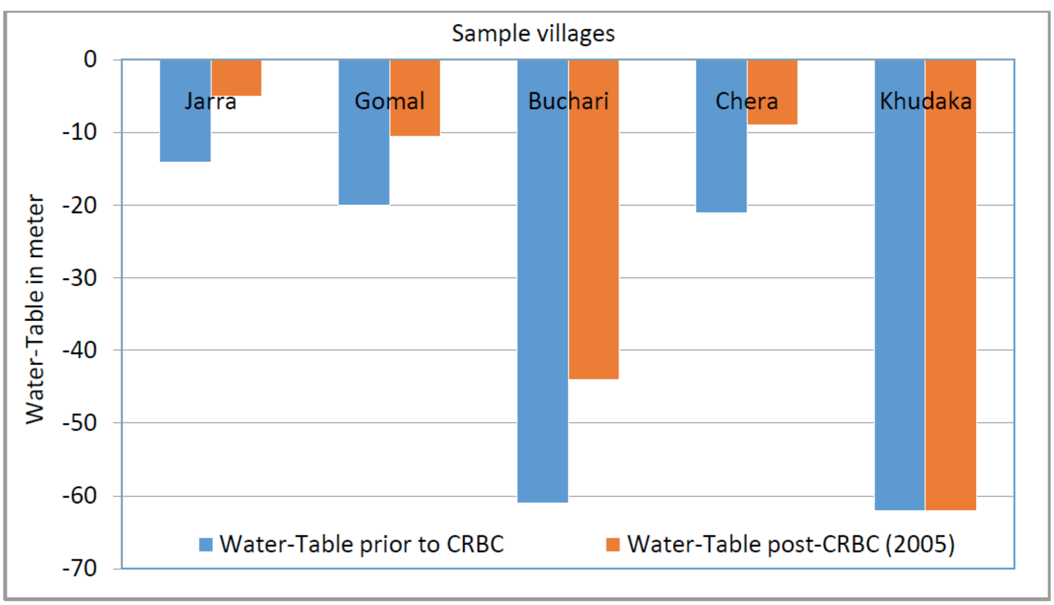

Figure 3: Pre and post CRBC change in water-table for the sample villages.

Table 1: Elevation and Ex Post CRBC Water-Table of the Sample Villages

Sample village	Elevation above sea level (in meters)	Water-table pre-CRBC below surface (in meter)	Water-table post-CRBC (in m) below surfacein 2005	Rising trend per year (in meters)
Jarra	191	-14 (1986)	-5	0.45
Gomal	186	-20 (1988)	-10.5	0.53
Buchari	184	-61 (1991)	-44	1.13
Chera	179	-21 (2000)	-9	2.4
Khudaka	190	-62 (1988)	-62	0

Source: Field survey April, 2005 and [23].

(Figure **3**; Table **1**). It means that the rate of rising trend is 2.4 meters per year. This indicates the rapid rise of water-table in the CRBC command area. During field survey, it was observed that in Chera several unpaved ponds along the watercourses were constructed. These ponds were used to store canal water and then supply it to their houses for domestic purpose using electric pumps. Hence, there was permanent seepage from the stagnant water of these unpaved ponds. Similarly, most of the irrigation channels are unlined. Besides this, intensive irrigation and introduction of more water loving crops have severely disturbed the equilibrium of water-table in the area. Khudaka, which is lying outside the command area showed no changes in the water-table both in pre and post CRBC situation.The analysis reveals that in the CRBC command area the water-table has been gradual inclined. This rise of water-table indicates that if this trend continued, soon the CRBC command area will become unfit for cultivation. This is one of the serious environmental degradation posed by the area (Table **1**).

Seepage and percolation from existing canal, distributaries, minors and watercourses are some of sources of recharge and rise of water-table in the CRBC command area. The lining of canal-distribution system may reduce significant amount of water losses. It is therefore recommended that the existing channels should be cemented. The analysis further reveals that in the CRBC command area the water-table has been gradually inclined. This is one of the serious environmental threats posed by the area. It is long-term but reversible negative impacts on the command area. The study found that after inception of CRBC, the water-table in the command area is rising at a rapid rate, which is a serious threat and can lead to the problems of waterlogging and salinity.

One of the major problems developed after large-scale surface irrigation in the CRBC command area was continuous rising of ground water-table, which was observed in several parts of the study area. This is mainly due to the unwise irrigation practices, lack of land levelling, absence of sub-surface drainage and trend towards water loving crops has inclined the water-table in the CRBC command area. Field survey together with the secondary data revealed that the water-table has been rising at an alarming pace particularly in the stage I and III.

In district D.I. Khan, the ground water-table varies from region to region. A large tract of saline groundwater is available in the western section, whereas the eastern section has good quality of fresh water all along the Indus river. The analysis reveals that in certain areas (Chera) the rise in water-table is as high as 2 meter per year. Such threatening situation may encourage waterlogging and inclining of saline water, which may reduce the agricultural productivity and cropping intensity. Contrary to this, wise irrigation practices may further increase the potentials of agricultural production.

3.4. Impacts Evaluation of CRBC on Drinking Water

In most part of the D.I. Khan district, groundwater is saline and unfits both for drinking and irrigation purpose. Prior to CRBC, majority of the household has used torrent or rain water for domestic purpose. Presently, majority of the household use canal water for domestic purpose. In the CRBC command area, more than half of the population is using canal water for domestic use. It has also been observed that in CRBC stage II and III, canal is the dominant source of drinking water. Resident considers this as one of the major benefit of CRBIP, since much of the area is rain-fed and groundwater is saline. According to field survey, in Gomal, Buchari and Chera respondents said that after CRBC the groundwater is gradually converting to better taste as compared to pre CRBC. In Chera, there is an age-old pond, from where local populations still fetch water for drinking. Prior to CRBC, this pond was recharged by rain and hill torrent water, but after

CRBC, canal water has become a main source of drinking water. In Buchari and Chera, several small ponds have been built on watercourses. However, outside the CRBC command area, before CRBC, people had to bring fresh water from quite far off areas. However, after the inception of CRBC, canal water became a major source for drinking. This is long-term and significant beneficial impact of CRBC on the local area.

3.5. Impact Evaluation of CRBC Using Checklisting Method

Checlisting is widely used for impact evaluation (Rahman and Khan 2008) and is applied for assessing CRBC impacts on water-table and related parameters. After the inception of CRBC, in the arid tract of district D.I. Khan several changes have been recorded. Such changes are both positive and adverse, when studied using selected indicators. CRBC has brought positive changes and supplied assured irrigation water. In the CRBC command area, mostly the groundwater is saline and unfits both for drinking and irrigation purpose. It has been observed that CRBC has provided assure water both for irrigation and domestic use and quenched the people’s thirst in the command area. Hence, the cultivable waste was brought under cultivation, choices of crops were increased, cropping intensity was accelerated, and revenue generation started that boost-up the agricultural production. This is one of the long-term, but significant positive impacts on the local residents (Table **2**). Despite such positive impacts, there are few negative implications due to unwise irrigation practices. The unlined irrigation channels, uneven fields, seepage and percolation have inclined the water-table and are serious threat to the precious land resources of D.I. Khan district. This is one of the long-term but reversible significant adverse impacts on the local area (Table **2**). The analysis further indicates that in the CRBC command areas, the water-table has been gradual inclined. If this rising trend in water-table continued, soon the CRBC command area will become unfit for cultivation. This is a long-term but reversible negative impact on the command area (Table **2**).

In major part of the district, groundwater is deep and saline, and unfits both for drinking and irrigation. Before CRBC, majority of the household has used torrent or rain water for domestic purpose. However, after CRBC many inhabitants considered CRBC as a major source of water supply. Presently, majority of the household use canal water for domestic purpose, whereas some use water supplied by the Public Health Engineering Department (PHED). WAPDA (2002) reported that in the CRBC command area, more than half of the population is using canal water for domestic purpose. According to household survey and FGDs, in CRBC stage II and III, canal is the dominant source of drinking water. The filed survey together with the FGDs reveals that local population considers CRBC water as one of the major benefit, since much of the groundwater is saline. This is long-term and significant beneficial impact of CRBC on the local area (Table **2**).

4. SUMMARY AND CONCLUSION

In the CRBC command area, because of poor awareness, farmers are unwisely using irrigation water. More preferences are given to water intensive crops such as sugarcane, rice and orchards. Similarly, intensive irrigation and unlined watercourses have also led to wastages. The CRBC was designed for crop-based irrigation but unfortunately it was used as demand base. Such mismanagement has inclined the water-table in certain part of the command area. Therefore, wise utilization of irrigation water will increase the life span of this mega irrigation project.

Table 2: Impact Evaluation of CRBC Using Checklisting Technique

Parameters	Nature of impacts															
	Adverse Impacts									Beneficial Impacts						
	ST	LT	R	IR	L	W	SI	M	N	ST	LT	L	W	SI	M	N
CRBC and Irrigation		X	X		X		X				X	X		X		
CRBC and Water-table		X	X		X		X									
CRBC and Drinking water											X	X		X		

Legend	ST	Short Term	IR	Irreversible	SI	Significant	R	Reversible	N	Negligible
	LT	Long Term	L	Local	M	Moderate	W	Wide		

Note: Table is based on individual household questionnaire, FGDs, secondary data.

One of the major problems developed after the large-scale surface water irrigation, is the continuous rise of water-table which has led to the problems of waterlogging and soil salinity. Water-table has started rising in this desert ecosystem due to large scale percolation, seepage from unlevelled fields and unlined channels. Besides this, introduction of water loving crops and crop based irrigation are other contributing factors. Presently, stage I is severely affected, whereas in stage II and III rate of rising water-table is quite rapid. This is a serious threat to the land resources of district D.I. Khan.

Sub-surface drainage is required when land is affected by high water-table. Other measures including vertical and biological drainage are implemented, where topography doesn't permit gravity sub-surface drain. Unfortunately, in the CRBIP command area sub-surface drainage was not provided as a mitigation measure, which has generated the twin problems within a few years after its inception. It is therefore recommended that to avoid the danger of waterlogging and salinity, sub-surface drainage need to be implemented as an immediate mitigation strategy.

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