Southern Punjab Poverty Alleviation Project (SPPAP)
<u>Assessment Study of Lining of Watercourse</u>
Community Physical Infrastructure Schemes (CPIs) - September, 2022

Monitoring, Evaluation and Research (MER)
National Rural Support Programme (NRSP)

IFAD
Investing in rural people

SPPAP

NRSP
National Rural Support Programme

Assessment Study on Lining of Watercourse - September, 2022
Rural Infrastructure Development through Community Physical Infrastructure Schemes (CPIs) under SPPAP.

"This assessment study reflects the significant role of the lined watercourses in the irrigation system of the project area. Particularly the technical analysis provides evidence-based results that how the intervention of lining of watercourse triggered positive and productive outcomes in terms of water conservation, irrigation efficiency that ultimately resulted in increased crop yield and income."

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Abstract of the Study

Sample of Study
8 Lined Watercourse
42% Sample of
Population (19 Watercourses)

Data Collection
8 Focus Group
Discussion (FGD)
97 Participants
(Farmers)

Water/Conveyance Losses
In Unlined Watercourse: 12%
In Lined Watercourse: 02%
Water Losses Reduced: 10%

Geographical Status of Sample
8 Villages
5 Union Councils
3 Districts
(Bahawalnagar, Bhakkar, Layyah)

Time Saving
34 Minutes Saved
in One Time
Irrigation Per Acre

Water / Conveyance Efficiency
In Unlined Watercourse: 88%
In Lined Watercourse: 98%
Efficiency Increase: 10%

Crop Yield
20% Increase

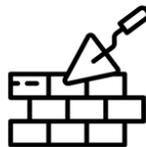**Labor Saving**
An Average PKR 1,500
Saved in One Time
Irrigation

Construction Quality
Ranked as "Good" in
all the 8 FGDs

Income
24% Increase

Since Completion of
CPIS "No" Repair and
Maintenance Work
Required Till Date

Lining of Watercourse
Positively Effect
Environment and "No"
Harm Occurred due to
Lined Watercourses

Introduction

The Southern Punjab Poverty Alleviation Project (SPPAP) is aimed to ensure a sustainable increase in the livelihood options for poor households, each household in the lowest poverty band is expected to benefit from several project activities. The SPPAP is financially assisted by International Fund for Agriculture Development (IFAD). The project is administratively supervised by Planning and Development Board, Government of Punjab through the establishment of a Project Management Unit (PMU) in District Bahawalpur. National Rural Support Programme (NRSP) as the Social Mobilization Partner (SMP) of SPPAP is implementing the project activities in all the ten districts *(Bahawalpur, Bahawalnagar, Muzaffargarh, Rajanpur, Rahim Yar Khan, Dera Ghazi Khan, Layyah, Bhakkar, Khushab, and Mianwali)* of Punjab.

NRSP is primarily responsible to implement social mobilisation activities, needs identification of SPPAP's components, and providing technical assistance in implementation of Community Physical Infrastructure Schemes (CPIs). The overall objective of SPPAP is to contribute to the reduction of poverty for 232,450 poor households in the project area. In poor rural communities, basic essential services such as water for irrigation, safe drinking water, drainage and sanitation, access roads and other infrastructure are missing or severely inadequate. SPPAP is investing in provision of improved basic infrastructure services in rural areas.

According to the Pakistan Bureau of Statistics (PBS), *"Agriculture constitutes the largest sector of our economy. The majority of the population, directly or indirectly, is dependent on this sector. It contributes about 24 percent of the Gross Domestic Product (GDP) and accounts for half of the employed labour force and is the largest source of foreign exchange earnings. It feeds the whole rural and urban population. Realizing its importance, planners and policymakers are always keen to have reliable area and production statistics of agricultural crops well in time.[1]"*

SPPAP has an explicit philosophy that the economic stability of small land-holding farmers is possible only by increasing their agricultural productivity. The most important factor for increasing agricultural production is to ensure the availability of water promptly and in the required quantity, which is an important element of an efficient irrigation system. SPAPP is ensuring this factor by improvement of water delivery and efficiency through the lining of watercourses that leads to increased crop yield and income for smallholder farmers.

In September 2022, an assessment study was conducted to assess the role of lined watercourses in reducing water losses and improving water efficiency that usually results in increased crop yield, income for farmers and *ceteris paribus*. The Monitoring, Evaluation, and Research (MER) section of NRSP carried out the study of the watercourse completed during Financial Year (FY) 2020-21. There were a total of nineteen watercourse schemes completed in the FY 2020-21 through simple random sampling eight watercourses (42% sample from the total population of 19 watercourses) were selected from the project

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[1] Pakistan Bureau of Statistics (PBS) – The prime official agency of Pakistan.

area. The key focus of the study was to assess and estimate the reduction in water losses, improvement in water efficiency, and change in crop yield.

Irrigation Schemes

The objective of the CPIs component is to provide financial support, via grants, for small-scale infrastructure in rural communities to meet their essential needs. Communities identified small landholding farmers the beneficiaries for irrigation schemes such as watercourses, tube wells, and turbines. The CPIs aimed to enhance access to basic infrastructure services for rural communities. Irrigation water scarcity is one of the most critical constraints in the target districts and is one of the underlying reason for the low level of productivity in the crop and livestock sectors. SPPAP has implemented irrigation schemes to assured increased water availability leading to higher command areas and better crop yields.

Irrigation schemes covered a large number of beneficiaries who are mainly small land-holding farmers. To minimize the conveyance losses and to improve irrigation efficiency SPPAP has implemented a significant number of watercourse schemes in the project area. In these CPIs unlined channels (watercourses) are lined. Table 1 showed the district-wise total number of lined watercourse schemes implemented in the second phase of the project i.e. from April 2018 to June 2022 (FY 2018-19 to 2021-22).

Sr. No.	District	No. of CPIS Implemented (Lining of Watercourse)	Length of Lined Watercourse		Command Area (No. of Acres)
			(in RFT)	(in km)	
1	Bahawalpur	4	6,670	2.034	620
2	Bahawalnagar	12	27,600	8.415	2,902
3	Muzaffargarh	1	2,567	0.783	290
4	Rajanpur	11	18,568	5.661	915
5	Layyah	28	55,420	16.896	6,365
6	Bhakkar	12	23,580	7.189	5,627
7	Khushab	1	1,800	0.549	200
Total		69	136,205	41.526	16,919

Table 1: Description of watercourse schemes completed in FY 2018-19 to 2021-22

Methodology

The analysis is based on irrigation experience for wheat crop yield during the FY 2020-21 after lining of watercourse. In this context, qualitative and quantitative analysis was undertaken. The technical analysis was carried out through discharge calculations, conveyance losses, and conveyance efficiency formulas. Moreover, Focus Group Discussion (FGD) was conducted with each group of farmers i.e. beneficiaries of the lined watercourse schemes in the selected sample area of the study.

Objective of the study

The main objective of the study was to assess that to what extent **conveyance losses** also known as water losses were reduced and **conveyance efficiency** also known as water or irrigation efficiency was improved through the lining of watercourse. Indeed these two factors paved the way to further estimate the percentage increase in crop yield. Secondly, to assess the role of watercourse schemes in achieving CPIS's prime objective i.e. enhanced access to basic infrastructure services in the project area.

Sampling

The sample was taken from the total number of watercourse schemes completed during the FY 2020-21. There were nineteen watercourse schemes completed in the FY 2020-21. In order to carry out the study, it was decided that the sample should be more than 30% of the total number of watercourses completed in the selected duration of the study. There were eight watercourses which is 42% of the population number (19 watercourses) selected through simple random sampling by using MS. Excel "Rand" formula.

Geographically, the sample consisted on three project districts (Bahawalnagar, Bhakkar and Layyah). On the basis of watercourse's respective community organization and district names, the watercourse IDs were generated in order to smoothly conduct further analysis and evaluation. Table 2 showed the geographical representation of sample watercourses.

Sr. No.	Random No.	Watercourse ID	District	Tehsil	Union Council (UC)	Community Organization (CO)
1	0.624819	JDBF-BNG1	Bahawalnagar	Bahawalnagar	Malik Pura	Jamal Deen Bhuk - F
2	0.202848	176F-BHK1	Bhakkar	Daryakhan	Daggar Qureshi	176/TDA - F
3	0.075983	DBWF-BHK2	Bhakkar	Daryakhan	Daggar Qureshi	Dera Bhacharan wala - F
4	0.522629	MHKF-BHK3	Bhakkar	Daryakhan	Baranga	Mohallah Kandi - F
5	0.504351	133J-LYH1	Layyah	Layyah	Chowk Azam 1	Chak No 133 TDA Basti Jalali
6	0.989662	133B-LYH2	Layyah	Layyah	Chowk Azam 1	Chak No 133 TDA Basti Babar
7	0.374935	142K-LYH3	Layyah	Layyah	Chowk Azam 1	Chak No 142 Basti Kumhar
8	0.077666	CHTW-LYH4	Layyah	Layyah	Sarishta Thal Jhandi	Basti Chutta Wala

Table 2: Geographical representation of sample watercourse

The basic description of watercourse in context of its length, command area and other features is presented in Table 3.

Sr. No.	Watercourse ID	No. of Households Beneficiaries	Lined Length (in km)	Unlined Length (in km)	Total Length (in km)	Command Area of lined watercourse (in acres)	Total Cost (PKR in million)
1	JDBF-BNG1	140	0.915	1.10	2.02	200	2.12
2	176F-BHK1	65	0.701	0.95	1.65	548	1.98
3	DBWF-BHK2	91	0.707	0.66	1.37	522	2.00
4	MHKF-BHK3	40	0.503	0.88	1.38	329	1.51
5	133J-LYH1	35	0.549	0.98	1.53	100	1.50
6	133B-LYH2	45	0.671	0.72	1.39	245	1.84
7	142K-LYH3	40	0.710	0.68	1.39	100	2.06
8	CHTW-LYH4	36	0.671	0.85	1.52	245	1.78
Total		492	5.43	6.82	12.52	2,289	14.79

Table 3: Key features of sample watercourse

Data Collection

Data collection was carried out in two segments; qualitative and quantitative data collected through Focus Group Discussion (FGD) and technical data to measure conveyance losses and conveyance efficiency through discharge calculation. A questionnaire was developed for holding FGD. All the responses were recorded in MS. Excel sheet for data analysis and findings.

Discharge Calculation

Manning's formula [2] was used to calculate the discharge of water from both unlined and lined watercourses. It is a relationship derived for estimating the flow velocity in the channel as given below;

$$V = 1/n * R^{2/3} * S^{1/2}$$

Where:

V	=	Velocity of flow (m/sec.)
n	=	Manning's roughness coefficient (given in Table 3)
R	=	Hydraulic Radius = A/P
		(A is area in square meters and P is wetted perimeter in Meters)
S	=	Bed Slops on the channel (m/m)

The channel capacity (Q) is calculated by;

$$Q_{(discharge)} = A/V$$

The brick lined rectangular section watercourses were constructed under SPPAP. The same section discharge was observed by using Manning's equation i.e. watercourse' bed and width. The hydraulic radius "R" is calculated through proportioning of bed width and depth. The slop "S" at the start point and end point was measured through the auto level set.

The roughness coefficient, also known as the Manning's "n" is the resistance or friction between the water and the channel. Channel conditions that have the greatest influence on "n" value are physical roughness of bottom and sides of the channel, vegetation, variation in size and cross-section, channel alignment, silting or sourcing and obstructions.

It is common practice to use two "n" values in designing small earthen channels since channel conditions change with time. The "n" value of a new straight and uniform channel is lower, the condition giving the fastest velocity. The "n" value of the aged and vegetated channel is high, the conditions requiring the larger cross-section. The higher value of "n" is used to ensure that the channel has adequate capacity under the conditions offering the most resistance. The lower value of "n" is used to determine if the velocity is non-erosive under the newly constructed or cleaned conditions. The value of "n" for small channel given in Table 4.

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[2] Manning's formula and coefficient "n" values under Table 4 described in Pakistan Poverty Alleviation Fund (PPAF) Manual for CPIS under irrigation schemes

Table 4: Manning's coefficient "n" values description

Description	Minimum	Maximum	Recommended "n" Value
Unlined Earthen Channels			
1. New-Straight and uniform	0.020	0.025	0.025
2. Aged and vegetated with:			
a) Short grass	0.030	0.040	0.035
b) Long grass	0.050	0.080	
Lined Channels			
• Concrete	0.012	0.018	0.014
• Brick plastered	0.012	0.018	0.013
• Brick unplastered	0.012	0.020	0.018

Reference to Table 4, the Manning's roughness coefficient "n" value 0.035 applied in discharge calculation of unlined watercourses. While value of "n" 0.013 applied in discharge calculation of lined watercourses on the basis of watercourses structure applied in SPPAP. The detailed discharge calculation of eight watercourses on the basis of Manning's formula is presented in Table 5.

Table 5: Lined and unlined watercourse discharge calculation

Watercourse ID	Description	Total Length	W	D	A	WP	R	S	n	S1/2	R2/3	V	Q	Head Loss	Q
		(km)	(m)	(m)	(m2)	(m)	(m)	(m/m)				m/s	m3/s		lps
Lined Watercourse															
JDBF-BNG1	Start Point		0.61	0.26	0.16	1.13	0.14	0.0005	0.013	0.02	0.27	0.46	0.073		73.20
	End Point	0.92	0.60	0.26	0.16	1.12	0.14	0.0005	0.013	0.02	0.27	0.46	0.072	0.00	71.63
176F-BHK1	Start Point		0.61	0.37	0.23	1.35	0.17	0.0003	0.013	0.02	0.30	0.40	0.091		90.72
	End Point	0.70	0.61	0.33	0.20	1.26	0.16	0.0004	0.013	0.02	0.29	0.45	0.088	0.00	88.35
DBWF-BHK2	Start Point		0.61	0.40	0.24	1.41	0.17	0.0004	0.013	0.02	0.31	0.47	0.116		115.89
	End Point	0.71	0.61	0.44	0.27	1.49	0.18	0.0003	0.013	0.02	0.32	0.42	0.113	0.00	113.41
MHKF-BHK3	Start Point		0.60	0.39	0.23	1.38	0.17	0.0003	0.013	0.02	0.30	0.41	0.095		94.95
	End Point	0.50	0.60	0.385	0.23	1.37	0.17	0.0003	0.013	0.02	0.30	0.40	0.093	0.00	93.38
133J-LYH1	Start Point		0.49	0.41	0.20	1.31	0.15	0.0003	0.013	0.02	0.28	0.38	0.076		76.21
	End Point	0.55	0.49	0.38	0.19	1.25	0.15	0.00035	0.013	0.02	0.28	0.40	0.075	0.00	74.82
133B-LYH2	Start Point		0.48	0.49	0.24	1.46	0.16	0.0007	0.013	0.03	0.29	0.60	0.141		140.86
	End Point	0.67	0.48	0.51	0.24	1.50	0.16	0.0006	0.013	0.02	0.30	0.56	0.137	0.00	136.92
142K-LYH3	Start Point		0.47	0.50	0.24	1.47	0.16	0.0004	0.013	0.02	0.29	0.45	0.106		105.84
	End Point	0.71	0.47	0.45	0.21	1.37	0.15	0.0005	0.013	0.02	0.29	0.49	0.104	0.00	104.04
CHTW-LYH4	Start Point		0.60	0.39	0.23	1.38	0.17	0.0005	0.013	0.02	0.30	0.52	0.123		122.58
	End Point	0.67	0.60	0.39	0.23	1.37	0.17	0.0005	0.013	0.02	0.30	0.52	0.121	0.00	120.55
Unlined Watercourse															
JDBF-BNG1	Start Point		1.12	0.26	0.36	1.74	0.21	0.0003	0.035	0.02	0.35	0.17	0.062		61.68
	End Point	1.10	1.10	0.27	0.37	1.74	0.21	0.0002	0.035	0.01	0.35	0.14	0.053	0.00	52.97
176F-BHK1	Start Point		1.21	0.30	0.45	1.96	0.23	0.00025	0.035	0.02	0.37	0.17	0.077		76.62
	End Point	0.95	1.25	0.29	0.45	1.99	0.22	0.0002	0.035	0.01	0.37	0.15	0.066	0.00	66.39
DBWF-BHK2	Start Point		1.30	0.32	0.52	2.14	0.24	0.0003	0.035	0.02	0.39	0.19	0.099		99.27
	End Point	0.66	1.31	0.30	0.48	2.09	0.23	0.0003	0.035	0.02	0.37	0.19	0.089	0.00	89.49
MHKF-BHK3	Start Point		1.25	0.30	0.47	2.02	0.23	0.0003	0.035	0.02	0.37	0.19	0.086		86.15
	End Point	0.88	1.00	0.28	0.36	1.64	0.22	0.0004	0.035	0.02	0.36	0.21	0.074	0.00	73.98
133J-LYH1	Start Point		1.19	0.29	0.43	1.91	0.22	0.0002	0.035	0.01	0.37	0.15	0.064		63.80
	End Point	0.98	1.15	0.28	0.40	1.83	0.22	0.00018	0.035	0.01	0.36	0.14	0.055	0.00	55.44
133B-LYH2	Start Point		1.30	0.41	0.70	2.41	0.29	0.00018	0.035	0.01	0.44	0.17	0.117		117.47
	End Point	0.72	1.25	0.34	0.54	2.13	0.25	0.0003	0.035	0.02	0.40	0.20	0.107	0.00	106.73
142K-LYH3	Start Point		0.90	0.29	0.35	1.54	0.22	0.0006	0.035	0.02	0.37	0.26	0.089		88.85
	End Point	0.68	0.70	0.29	0.29	1.28	0.22	0.0007	0.035	0.03	0.37	0.28	0.080	0.00	79.84
CHTW-LYH4	Start Point		1.34	0.25	0.40	1.99	0.20	0.0006	0.035	0.02	0.34	0.24	0.095		94.63
	End Point	0.85	1.33	0.26	0.41	2.00	0.21	0.0004	0.035	0.02	0.35	0.20	0.082	0.00	82.06

Equipment and Material Used

The auto level set was used to measure the slope at the start point and end point of 100 meters length in two sections of each lined and unlined portion of watercourses. The measurement tape was used to measure the length of 100 meters while steel tape was used to measure the wet depth and length of the watercourse at the start point and end point.

Focus Group Discussion (FGD)

The focus group discussion was conducted on the basis of following parameter.

- Beneficiaries (farmers) of watercourse having their farms premises at three points "Head, Middle and Tail" of watercourse.
- There were total 97 farmers (beneficiaries of watercourse CPIs) participated in eight FGDs, the district and CPIs wise number of FGD participants is showed in Table 6.
- A questionnaire was developed to collect quantitative and qualitative data.

Sr. No.	District	WC - ID	FGD Participants			
			Head	Middle	Tail	Total
1	Bahawalnagar	JDBF-BNG1	3	3	5	11
2	Bhakkar	176F-BHK1	2	4	3	9
3	Bhakkar	DBWF-BHK2	4	3	7	14
4	Bhakkar	MHKF-BHK3	6	2	4	12
5	Layyah	133J-LYH1	4	5	6	15
6	Layyah	133B-LYH2	3	4	3	10
7	Layyah	142K-LYH3	5	2	8	15
8	Layyah	CHTW-LYH4	3	3	5	11
Total			30	26	41	97

Table 6: No. of participants in FGDs

Findings of the Study

Conveyance Losses

On the basis of discharge values calculated at the Start Point and End Point under Table 5, conveyance losses were quantified in the selected sample watercourse through following conveyance losses formula[3]. Conveyance losses formula is presented below.

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[3] Impact of Watercourse Lining on Water Conservation conducted by Mehran University of Engineering and Technology, Jamshoro, Pakistan.

Conveyance Losses
Conveyance Losses (%) $Q_L = \dfrac{Q_s - Q_e}{Q_s} \times 100$ Where, Q_s = Start Point Q_e = End point Q_s and Q_e are observed in m³/sec and lps (liter per second)

Sr. No.	Watercourse ID	Total Length	Discharge		Conveyance losses%	Conveyance losses% Per km
			Start Point	End Point		
		(km)	Q_s	Q_e	$(Q_s-Q_e)/Q_s \times 100$	
			Lined Watercourse			
1	JDBF-BNG1	0.92	73.20	71.63	2.14%	2.34%
2	176F-BHK1	0.70	90.72	88.35	2.61%	3.73%
3	DBWF-BHK2	0.71	115.89	113.41	2.14%	3.03%
4	MHKF-BHK3	0.50	94.95	93.38	1.65%	3.29%
5	133J-LYH1	0.55	76.21	74.82	1.82%	3.32%
6	133B-LYH2	0.67	140.86	136.92	2.80%	4.17%
7	142K-LYH3	0.71	105.84	104.04	1.70%	2.40%
8	CHTW-LYH4	0.67	122.58	120.55	1.65%	2.46%
Average					2.07%	
			Unlined Watercourse			
1	JDBF-BNG1	1.10	61.68	52.97	14.12%	12.84%
2	176F-BHK1	0.95	76.62	66.39	13.35%	14.06%
3	DBWF-BHK2	0.66	99.27	89.49	9.85%	14.93%
4	MHKF-BHK3	0.88	86.15	73.98	14.13%	16.06%
5	133J-LYH1	0.98	63.80	55.44	13.10%	13.37%
6	133B-LYH2	0.72	117.47	106.73	9.14%	12.70%
7	142K-LYH3	0.68	88.85	79.84	10.14%	14.91%
8	CHTW-LYH4	0.85	94.63	82.06	13.29%	15.63%
Average					12.14%	
Difference of losses between lined and unlined watercourse					10.08%	

Table 7: Conveyance (water) losses estimation of lined and unlined watercourses

The determination of conveyance losses and percentage of conveyance losses of lined and unlined sections is presented in Table 7. Comparing the average conveyance loss of 12% from unlined sections to the average conveyance loss 2% from lined sections of the watercourses, it was estimated that the lining reduced water loss by 10%. However, the 2% conveyance losses in the lined and improved portions of the selected watercourses can be assumed due to evaporations losses which is a natural occurrence. Lining of watercourse significantly eradicated water losses in another dimension; as reported by farmers in FGD,

mice used to dig and make holes in unlined channels (before lining of watercourse) that resulted in seepage and conveyance losses which is quite not possible after lining of watercourse.

Conveyance Efficiency

The following formula[4] was used in order to determine conveyance efficiency in the lined and unlined sections of the selected watercourses.

Conveyance Efficiency
Conveyance Efficiency (%) Q_E = $\dfrac{Q_e \times 100}{Q_s}$

Figure 1 showed graphical comparison of the conveyance efficiency % of lined and unlined watercourses while Table 8 showed change in conveyance efficiency of the lined and unlined watercourses.
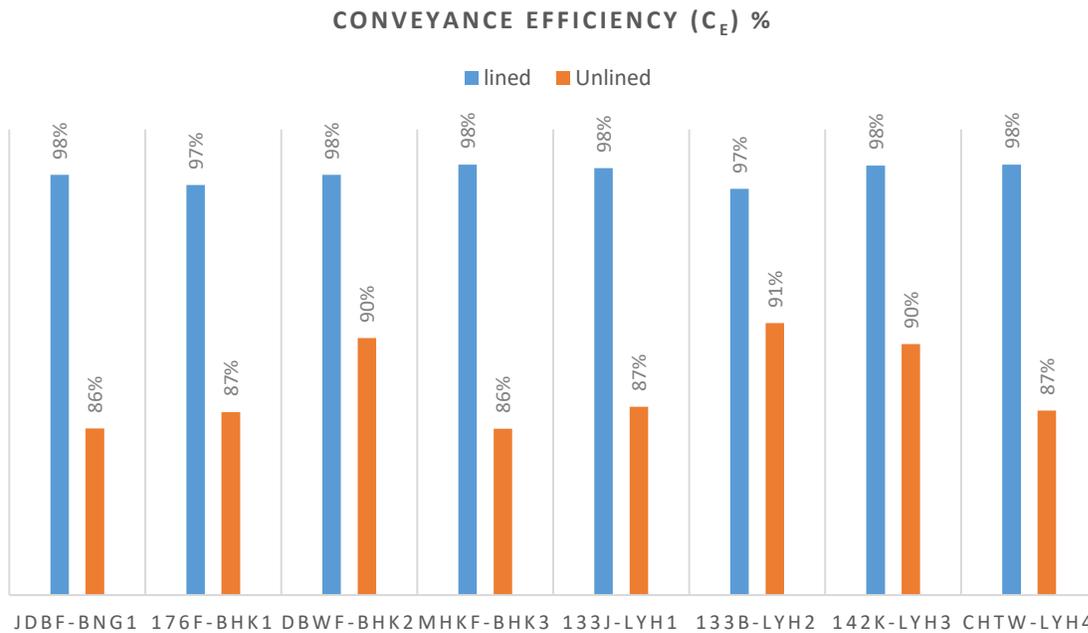
CONVEYANCE EFFICIENCY (C_E) %

Figure 1: Conveyance efficiency % of lined and unlined watercourses

Table 8 showed an average 98% conveyance efficiency in lined watercourses while 88% in unlined watercourses. It was observed that less percentage of conveyance efficiency in unlined sections of watercourses is explicitly due to improper maintenance of watercourses, the presence of vegetation, poor alignment and uneven edges of watercourses.

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[4] Impact of Watercourse Lining on Water Conservation conducted by Mehran University of Engineering and Technology, Jamshoro, Pakistan.

Sr. No.	Watercourse ID	Lined Watercourse	Unlined Watercourse	Difference
		Conveyance efficiency %	Conveyance efficiency %	Increase %
		Q_s/Q_e x 100	Q_s/Q_e x 100	
1	JDBF-BNG1	98%	86%	12%
2	176F-BHK1	97%	87%	11%
3	DBWF-BHK2	98%	90%	8%
4	MHKF-BHK3	98%	86%	12%
5	133J-LYH1	98%	87%	11%
6	133B-LYH2	97%	91%	6%
7	142K-LYH3	98%	90%	8%
8	CHTW-LYH4	98%	87%	12%
Average		**98%**	**88%**	**10.08%**
An average overall increase in water efficiency				**10%**

Table 8: Conveyance (water/irrigation) efficiency estimation

Water Saving

Water saving is estimated through the subtraction of conveyance losses percentage from both unlined and lined watercourses in the sample. It was estimated that 10% water saving obtained after the lining of watercourse in one time irrigation; while there are only 2% water losses observed in lined watercourse comparing to 12% of unlined watercourse.

Water losses % estimated in unlined watercourse	12%
Water losses % estimated in lined watercourse	2%
Water saving (Unlined water losses % - Lined water losses %)	**10%**

Time Saving

Time is the most important factor considered in an irrigation system. As reported by farmers in FGDs, improved and lined watercourse consumes less time to irrigate fields compared to the unlined watercourse. The impact of the lined watercourse in terms of time-saving was calculated by calculating the average response of farmers located in three heads of the channel i.e. head, middle, and tail. The time was calculated in minutes. Table 9 showed time-saving due to lined watercourses; estimated at the head 25 minutes, middle 34 and at the tail 42 minutes to irrigate one acre of land.

Sr. No.	WC - ID	Time Before - Unlined Watercourse (in minutes)			Time After - Lined Watercourse (in minutes)			Change in Time (in minutes)		
		Head	Middle	Tail	Head	Middle	Tail	Head	Middle	Tail
1	JDBF-BNG1	80	90	120	60	60	75	20	30	45
2	176F-BHK1	120	145	180	95	110	140	25	35	40
3	DBWF-BHK2	120	135	150	95	105	105	25	30	45
4	MHKF-BHK3	125	150	180	110	130	150	15	20	30
5	133J-LYH1	190	230	275	140	170	190	50	60	85
6	133B-LYH2	100	120	150	70	85	120	30	35	30
7	142K-LYH3	90	115	150	75	90	120	15	25	30
8	CHTW-LYH4	60	90	120	40	55	90	20	35	30
Average Time Saved (in minutes)								25	34	42
Overall Average Time Saved (in minutes)										34

Table 9: Time saving estimation in lined and unlined sample watercourse

The estimated overall average was 34 minutes which means that improvement and lining of the watercourse contributed to a time-saving of 34 minutes for one time irrigation to one acre. The lining of the watercourse mitigated the chances of breaches to a large extent while the evenness of the channels' bed helps the swift flow of water with less resistance. These factors ultimately contributed to time reduction to irrigate the area. The key finding related to time-saving was observed at the point of the tail where an average of 42 minutes of time-saving was acquired after lining of the watercourse.

Crop Yield

There was only one crop "Wheat" selected to estimate the impact on crop yield during the year 2020-21. The values of crop yield were recorded and an average value was taken from the response of participants of FGDs. The data regarding wheat crop yield in the command area of eight watercourses of the sample is showed in Figure 2 and Table 10 which describes crop yield before and after the lining of the watercourse and the change in crop yield.

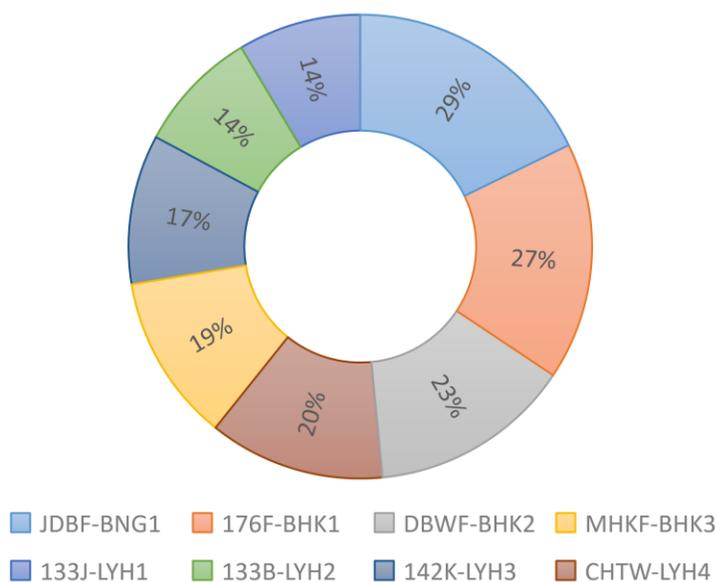% Increase in crop yield (Wheat) after lining of watercourse

JDBF-BNG1   176F-BHK1   DBWF-BHK2   MHKF-BHK3
133J-LYH1   133B-LYH2   142K-LYH3   CHTW-LYH4

Figure 2: Increase in crop yield after lining of watercourse

An overall average increase in the wheat crop was estimated six maunds (1 maund = 37.32 kg, commonly known as 1 maund = 40 kg) which is the 20% average increase in wheat crop yield estimated after lining of the watercourse. The increase in crop yield is also the result of water saving, swift flow of water, and proper number of irrigations numbers applied to the wheat crop after the lining of watercourses.

Sr. No.	WC - ID	Before - Unlined watercourse (in maunds)	After - Lined watercourse (in maunds)	Change in Yield (in maunds)	% Change in crop yield after lining of watercourse
1	JDBF-BNG1	28	36	8	29%
2	176F-BHK1	30	38	8	27%
3	DBWF-BHK2	30	37	7	23%
4	MHKF-BHK3	32	38	6	19%
5	133J-LYH1	35	40	5	14%
6	133B-LYH2	35	40	5	14%
7	142K-LYH3	30	35	5	17%
8	CHTW-LYH4	35	42	7	20%
	Average	32	38	6	20%

Table 10: Crop yield estimation before and after lining of watercourse

Increase in income

The increase in crop yield is directly proportional to the increase in income. The wheat crop per maund rate i.e. PKR 1,800 (wheat rate set by Punjab Government in FY 2020-21[5]) was benchmarked to calculate the change in income. The results after applying PKR 1,800 before (unlined watercourse) and after (lined watercourse) is showed in table 11. There is an average PKR 14,025 which is a 24% increase in income per acre observed due to improved water efficiency that fruitfully affects crop yield which eventually raised the income of farmers.

Sr. No.	WC - ID	Per Acre Income Before (PKR)	Per Acre Income After (PKR)	Difference in income (PKR) - Per Acre	% Change in income after lining of watercourse – Per Acre
1	JDBF-BNG1	50,400	64,800	17,600	35%
2	176F-BHK1	54,000	68,400	17,600	33%
3	DBWF-BHK2	54,000	66,600	15,400	29%
4	MHKF-BHK3	57,600	68,400	13,200	23%
5	133J-LYH1	63,000	72,000	11,000	17%
6	133B-LYH2	63,000	72,000	11,000	17%
7	142K-LYH3	54,000	63,000	11,000	20%
8	CHTW-LYH4	63,000	75,600	15,400	24%
Average		57,375	68,850	14,025	24%

Table 11: Income estimation before and after lining of watercourse

Cropping Pattern

There was a traditional trend of cropping pattern found in the study area; mostly six months-based seasonal crops wheat, cotton, and sugarcane are being cultivated. While in the district Bahawalnagar rice crop is also cultivated. But no significant change regarding cropping pattern in the study area was observed after lining of watercourses.

Labour Saving

Through the discussion with farmers, it was revealed that lining of watercourse also reduced labour expenses occurs at the time of irrigation which means the intervention contributed to saving money. According to farmers of FGDs, before lining of the watercourse, two to three men are deputed at different spots of the watercourse in order to control and ensure proper watering into the fields. The deputed labour also cleans the vegetation and removes extra silt from unlined watercourse to ensure timely reach water into fields. After the lining of watercourse labour expenses is significantly reduced.

Sr. No.	WC - ID	Per Acre Labour Expense - Unlined watercourse (PKR)	Per Acre Labour Expense - Lined watercourse (PKR)	Expenses Reduced Per Acre (PKR)
1	JDBF-BNG1	2,400	800	1,600

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[5] Wheat price in FY 2020-21 - Agriculture Marketing Information Service (AMIS), Directorate of Agriculture (Economics & Marketing) Punjab, Lahore.

2	176F-BHK1	1,600	-	1,600
3	DBWF-BHK2	2,400	-	2,400
4	MHKF-BHK3	1,600	800	800
5	133J-LYH1	1,600	-	1,600
6	133B-LYH2	2,400	800	1,600
7	142K-LYH3	2,400	800	1,600
8	CHTW-LYH4	1,600	800	800
Average expense reduced on one-time irrigation after lining of watercourse (PKR)				1,500

Table 12: Description of saving on labour expenses

After lining of watercourse it has become very easy to control the water. This was observed while diverting water even for one acre of land because each farmer is allocated a proprietary right to draw all the flow of watercourse on his turn. On the basis of farmers' view, an average labour PKR 800 per day for one person was charged. It was observed that per acre labour expense was reduced in one time irrigation after lining of the watercourse. Table 12 showed an average PKR 1,600 saving in one time (one day) irrigation after the improvement of watercourses. There were three FGDs (176F-BHK1, DBWF-BHK2, 133J-LYH1) responded that after lining of watercourse they do not need any labour at the time of irrigation; so they saved the total amount of labour cost after lining of the watercourse.

Livelihood Opportunities

Rural community infrastructure labour work in form of lined watercourses created labour employment opportunities as well. Although these opportunities were in the form of daily wages, but they provided a supportive push to the poor segment of the community to survive in inflation and unemployment crises. Table 13 showed the local labour deployment status in eight villages where the lining of watercourse work was carried out.

Sr. No.	WC - ID	Skilled	Unskilled	Total
1	JDBF-BNG1	1	4	5
2	176F-BHK1	4	14	18
3	DBWF-BHK2	3	6	9
4	MHKF-BHK3	1	10	11
5	133J-LYH1	-	3	3
6	133B-LYH2	-	8	8
7	142K-LYH3	-	-	-
8	CHTW-LYH4	-	4	4
Grand Total		9	49	58

Table 13: Status of local labour utilization

Effect on Environment

Farmers from all the FGDs reported that improvement and lining of watercourse have very positive and pleasant effects on surrounding environment. According to farmers, the removal of vegetation, silt, and control of seepage provides a clean atmosphere and people of the area can smoothly walk in their fields which was very difficult in case of unlined watercourse. Participants of FGDs also reported that in the construction work of lining of watercourse no major loss occurred to trees hence watercourse alignment did not disturb any environmentally sensitive area.

Quality of watercourse

The quality of watercourse construction work was also asked through the questionnaire of FGD. There were three following options given to rank the quality of construction work under SPPAP.

➢ Good
➢ Moderate
➢ Low

The response was recorded by calculating the average of the majority of respondents in each FGD. The results remained very impressive as all the watercourses were ranked as "Good" quality of construction work and farmers were found overwhelmingly satisfied with the quality of watercourses.

Operation & Maintenance

The quality of construction work was also cross verified by asking a question related to any maintenance work done after the completion of physical work i.e. after June 2021 to the current time period (FGD month September 2022) about 15 months later. It was responded that no operation and maintenance work was required during the said period. Indeed, the response of FGD participants (farmers) in "No" was a clear indication that all the sample watercourses were constructed with good quality material and masonry work.

There was another succeeding question in case if FGD participants responded "Yes" that they did O&M work after handing over the scheme to the community. The question was "How the expense of O&M was made through" there were two options for answer this question; whether the work was done through utilization of O&M budget of the CO account solely or community also contributed to O&M cost. But to date, there was no need for repair or maintenance by the concerned communities hence this question was omitted in all the FGDs.

Mitigate Social Disputes

The lined watercourses played a pivotal role in the mitigation of social disputes in the area. Before the lining of water courses, due to improper control of water and theft of water, there were social conflicts and disputes in communities. It was reported in three FGDs (one in District Bhakkar and two in District Layyah) that they often faced social disputes in their village which have been mitigated after lined watercourses.

Conclusion

The analysis of the study revealed very encouraging results that it can be assumed that all the watercourses contributed to reducing water losses and improved water efficiency. The average conveyance efficiency in lined watercourses is 98% while in unlined watercourses it is 88%. However, the overall change in conveyance efficiency was 10%.

➢ The results from the study can be applied to the total command area of 16,919 and the total length of the lining of watercourses 41.526 km covered in a period of four years i.e. during the FY 2018-19 to 2021-22. So it is estimated that conveyance losses are reduced by 10%, and water

efficiency in irrigation is also improved by 10% which further resulted in a 20% increase in crop yield and time savings of 34 minutes in one time irrigation.

Based on the study findings, it can be concluded that the lining of watercourses has a remarkable effect on seepage control which augmented water saving and has a substantial effect on water resource conservation. The overall results of the study showed that the intervention of watercourse evidently contributed to achieve the objective of CPIS under SPPAP; i.e. enhanced access to basic infrastructure services in the project area.

Annexures

Annexure – 1: Questionnaire for Focus Group Discussion Part – A

Sr. No.	Questionnaire Part - 1	
	Basic Information	
1	Watercourse ID	
2	District	
3	Tehsil	
4	Union Council	
5	Community Organization (CO)	
6	No. of Participants in FGD	
6.1	Farmers belonged to Start	
6.2	Farmers belonged to Middle	
6.3	Farmers belonged to Tail	
	Questions	**Response**
1	Did any local residents participate as a labourer in watercourse construction	
1.1	1- Yes 2- No	
1.2	If "Yes" , no. of skilled labour	
1.3	If "Yes" , no. of unskilled labour	
2	No. of farmers benefitted from watercourse	
3	No. of total acres irrigated through watercourse channel	
4	Do you think lining of watercourse has positive impact on environment	
4.1	1- Yes 2- No	
4.2	If "No" note the relevant comments	
5	How do you rate quality of construction work (lining of watercourse)	
5.1	1- Good 2- Moderate 3- Low	
6	Till to date, any cost incurred on maintenance of watercourse	
6.1	1- Yes 2-No	
6.2	If "Yes" how expenses were made through	
6.3	1- O&M budget from CO account	
6.4	2- O&M Budget and with self-contribution	
7	Did you face/experience of social conflicts before lining of watercourse	
7.1	1- Yes 2-No	
7.2	If "Yes" did the lining of watercourse contribute to mitigating social conflicts	
7.3	1- Yes 2-No	
8	Have you change your cropping pattern after lining of watercourse	
8.1	1- Yes 2-No	
8.2	If "Yes" name of new crop cultivated by farmers, if more than 1 crop then put comma after each crop name	

Annexure – 2: Questionnaire for Focus Group Discussion Part - B

Questionnaire Part -2								
Crop Yield per Acre (in maunds)								
Before			After			Net Difference		
Time Saving								
Unlined watercourse (Before)- in minutes per acre			Lined watercourse (After)-in minutes per acre			Net Difference - in minutes per acre		
Head	Middle	Tail	Head	Middle	Tail	Head	Middle	Tail
Cost Saving in Labour Head								
Labour cost incurred before (for one time irrigation)		Labour cost incurred after (for one time irrigation)		Net Difference			An average no. of time require for water to crop (in minutes)	
Income (in PKR)								
Income per acre before lining of watercourse		Income per acre after lining of watercourse		Net Difference in income				

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