

# **Efficacy of Watercourse Lining in Sindh**

### -A Review Study in Relation with Kohistan Region

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#### Abstract

The total number of watercourses in Pakistan is about 110,000 and particularly in Sindh it is about 46,699, out of which 7576 have been lined from 1977 to 1998 and from 2004 to 2015; 22,479 have been lined and the remaining 16,644 still require improvement. At the current rate of progress, the lining of remaining watercourses would further take about 21 years. As designed life of the improved watercourse is about 25 years. By the time of ending of many watercourse improvement programs, there will again require the rehabilitation on many of the earlier watercourse lining schemes. Generally two types of watercourse lining are practiced in Sindh i.e. Rectangular Lined Watercourses (with single and double brick walls) and Trapezoidal Concrete Lined Watercourses. Because of efficient, effectiveness, easy maintenance and repair work, the Rectangular Lined Watercourse is more frequently practiced in Sindh. It is now suggested that: to renovate the watercourses an accelerated program should be started and the system (with the sense of terms and conditions) for renovation of watercourses program should also be changed. The research work towards different types of lining materials for watercourse should be conducted. Looking to the brief review it is suggested that a fiber glass type plastic material with semi-circular or U-shaped, pre-cast fabricated RCC Trapezoidal or Parabolic in place of brick mortar and concrete could be used for watercourse lining. This methodology, proposed to be used, will enable us to determine cost-benefit ratio, life span and such other parameters for its feasibility under variable climatic conditions of Sindh (North Sindh being dry and hot, while South Sindh semi-humid and warm).

#### **Keywords**

Watercourse Lining, Water Management in Pakistan

#### **1. Introduction**

Pakistan is basically an agricultural country and most of its economy depends on production of raw material-food, fiber, timber, hides, etc. Due to existence of country in arid and semi-arid climatic region, artificial irrigation has been practiced for times immemorial. The irrigation system consists of dams, barrages, head works and contiguous network of canals and watercourses. Before the construction of irrigation structures, the water table in irrigated areas varied from 7.0 to 15.0 meters below the ground surface [1].

About 47% to 53% water losses take place from irrigation channels in Pakistan. About 110,000 watercourses are in Pakistan. The length of these water courses ranges from a fraction f 01 kilometer to 04 kilometers and the discharge rate ranges from 28 to 120 Liters/seconds. The net applicable water at the head of watercourse is 112 MAF, out of which 51 MAF (about 46%) is lost during conveyance to fields. Such a water loss in watercourses can be reduced effectively with application of certain innovative technologies including channel lining [1].

It may be added that a continuous loss of water (through seepage and percolation) has created a twin problem of salinity and waterlogging, rendering the precious lands unproductive. Waterlogging in Indus Plain of Pakistan has affected 37.6% of gross command area with 15% severely waterlogged land. Besides, salinity has occupied 78% of ground surface with 39% severely saline. To avert such a situation, following two measures could be adopted: 1) Curative and 2) Preventive [1].

The first measure is difficult, expensive and time-consuming. The second one is easy to practice, economical and effective. This would help control both the salinity and waterlogging problems. It includes water management practices, such as watercourse improvement for efficient flow of irrigation water, adopting irrigation scheduling of crops or application of irrigation water to crops according to their requirements, etc. [1].

By adopting such practices, not only the land is prevented from salinity and waterlogging on farm level but an appreciable quantity of precious irrigation water could be saved which can be utilized either to bring more area under cultivation or to conduct leaching and reclaiming process in salt affected lands [1].

This review article depicts the present scenario of watercourses in Sindh and suggests future strategy for development.

## Present Status and Future Strategies of Watercourse Lining in Sindh

Vast lands of Pakistan required a gigantic irrigation system; and therefore, the storage reservoirs, barrages, canals, watercourses and other structures have been erected. This huge irrigation system has no doubt been a blessing to the country in cultivating lands for raising crops and rearing animals. But on the other hand, it has shown a curse for the reason of break-out of the problem of salinity and waterlogging. Such a problem has been caused by water losses occurring in the

distribution system. It is reported that minors often lose water more than 50% of its discharge at its head, resulting serious deficiency of water at its tail. Half of the water is lost during its conveyance from moga of watercourse to the farmer's fields [2]. This loss of water put adversely affects on the command capacity of watercourses to irrigate the land. With a few exceptions, this condition is common to most of the 110,000 watercourses in Pakistan. The ultimate key to economical deduction of these water losses lies in a Farmer-Government Partnership to better operate and manage the irrigation system. A first step in this direction is to ensure that watercourses are constructed in an efficient and optimal manner.

Watercourse improvement is an utmost necessity of today's irrigated agriculture in Pakistan. Construction and maintenance of watercourse, being the responsibility of water users as well, have not received due technical considerations; hence, there are significant irrigation water losses throughout the country. It is observed that the channel alignments, cross-sections and gradients have not been constructed with proper engineering design.

Unfavorable water velocity that is causing to lead up the silting & soil erosion, overtopping, narrowing of berms and dead storage of water in the watercourses. These are the factors which have ultimately resulted in considerable water loss. Moreover, poor, haphazard and inadequate watercourse maintenance has lead to an excessive vegetative growth, breaches and overtopping. Cutting through berms for turnouts, borrowing soil from adjoining fields to built checks in the watercourse, and animal (Rates) holes are additional factors for increasing the water losses (Figures A1-A3 in Annexure-I). Therefore, several irrigation improvement programs have been taken up to substantially conserve/save the water. Attempts have been made to rebuild the watercourses according to the proper engineering design with provision of structures for turnouts and checks (From 1977 to 2015 showing in Table A1, Annexure-II).

To overcome the seepage losses from canals and watercourses, lining of watercourses on cost-sharing basis have been undertaken by Provincial Government, On Farm Water Management department, through its Directorates. Out of 46,699 watercourses, only 7576 watercourses have so far been successfully lined/renovated up to 1998 [3].

In Sindh Province a number of projects have been completed. The progress of achievements under different projects, involving watercourse improvements that is given in **Table A1** shows the brief history of Watercourse Lining Programs in Sindh Province from 1977 to 2015. From **Table A1** is clear that during different years; the progress of watercourse lining is different and there is no any sequence of lining all the projects. So there is a need to manage all the projects with a systematic way to lining the watercourses. From the literature it is observed that the designed life is 25 year of lined watercourse so the earlier schemes needs rehabilitation and there must be continuous process of lining/renovation.

From Table A1 (column no. 04) federal government planned to undertake renovation of 5000 watercourses in Sindh province, under National Accelerated Water Management Project (1997-98); this scheme was for three years. The program could not be started due to lack of funds and only 72 watercourses were completed. The main objectives of watercourse lining were to: 1) Reduce water losses, 2) Reduce waterlogging, 3) Increase cropping intensities by 10% to 20%, 4) Increase irrigation efficiency and 5) Reduce siltation.

Under approved OFWM Project Phase-IV: it was proposed that 2705 watercourses will be lined in Sindh during 2001-2005 (05 years program), and this will go a long way in controlling the wastage of waterlogging in the province. But due to some governmental issues that program was not executed.

From the survey of literature on Water Management, it is found that Egypt, Jordan and Israel have controlled the seepage losses by lining the channels. Besides this the author has also reported that these countries have been able to reduce the water loss rate by 25% through regular cleaning and alignments of the watercourses as per engineering requirements. This is a simple practice that can be adopted by the farmers in Sindh province. To reduce more water losses, these countries have further embarked on check outlets of permanent structures based on hydraulic design [4].

#### 2. Material Used for Watercourse Lining

Various experiments have been conducted on different lining material for watercourse lining:

It is recommended (while using) RCC prefabricated lining which is relatively cheaper, more effective, convenient technique which less time to line as compare to the conventional technique (*i.e.* 9 inch wall rectangular design). It reduces the cost of skilled labor about 50%, and also the cost by 25% then rectangular lining. Seepage losses in case of RCC slabs are about 48% than in Trapezoidal Bricks lining [5].

The research studies conducted on different lining materials such as; concrete, cement, lime, brick powder (Surkhi), shingle and marble powder, RCC slabs (pre-cast) and plastic with combination of different material in different proportions. They took up work on 681 m long of watercourses, having 11 sections of different structures/shapes, University Research Farm, Agricultural Engineering Department, Engineering University Peshawar from June 1986 to 1990, keeping in view the quality of material used, cost per sq. meter of material and with controlling the seepage rate. Their study reveal that the highest cost and more seepage occurred at the 5<sup>th</sup> section 68.8 m long, 0.005 - 0.08 m concrete (1:3:6) Bed and 0.1 - 0.2 m undressed stone (1:6) sides. Whereas, the 4<sup>th</sup> section (64.0 m long, 0.005 0.08 m concrete (1:3:6) bed and 0.11 m brick (1:5) sides) had the lowest cost of construction and less seepage as compared to all other sections [6].

After conducting experiment on different material for lining the watercourses, it is reported that the use of synthetic material in canals linings with Geotextile and related materials have been widely used for canal lining during the last few years in Egypt. Egypt at present produces PVC material. They are usually made from only four synthetic Polymers: Polyamide, Polyester, Polyethylene and polypropylene. Two main types of fabrics used for geotextile are: 1) Woven and 2) Non-Woven ones [7].

A research study conducted in Pakistan on performance of various lining materials such as; Brick, Bentonite, Soil Sealant, polyethylene and synthetic rubber. He found:

Many sites specific field problems in brick lining [8].

Rapid deterioration in field by local bentonite lining (compacted soil lining).

Lot of improvements needed in sealing properties under varied local conditions, by using the soil sealant/emulsions under varied local conditions.

Polyethylene sheets are damaged by weed growth, rodent attacks, other animals, trace passing etc.

Synthetic Rubber membranes under protective covers gave fairly good results with having some bondage problems [8].

It is reported from 90 years experience of Bureau of Reclamation (BR) for irrigation canal lining, United States of America. Many canal lining materials are used. Presently concrete linings, composite earth linings, buried plastic linings are main lining materials that are practiced [9].

He conducted that reinforced concrete, thick compacted earth, PVC with sand and gravel cover all provide acceptable and cost effective seepage control; and he suggested that many new materials are also being introduced to the market that look promising as canal liners [9].

In USA, labor is expensive; therefore Polyvinyl Chloride (PVC) bonding becomes expensive. Over lap of PVC sheets by three feet of sand and gravel on to is as good as, if not better than, chemical bonding [9].

In USA, lining is as durable as against Polyethylene has a floating problem [9].

It is reported that Lime is as abundant local material which has been used in construction of buried canal/pipe for a long time. Lime-Soil mixture lining has advantages of low cost and acceptable effect of seepage control, particularly used in mild climate areas. Usually cement mortar or lime mortar are applied on the lining surface to improve the permeability [10].

Soil-Cement lining is a lining method which is suitable in the areas lacking in sand and gravel materials, particularly used in mild climatic regions. Sandy loam can be made for lining mixture [10].

Masonry lining is a traditional lining method in China. It has disadvantages of low seepage control, high roughness, high cost and great hand work. To improve its permeability, grouting clay mortar or lime mortar, providing lime soil mixture layer or membrane underneath masonry have been used and the result showed that the seepage loss was greatly reduced [10].

Membrane lining is impermeable, light in weight and easy to pave. It has been widely used since 1950s the development of plastic industry. To extend its ser-

vice life, soil, soil cement, lime-soil mixture, concrete or masonry are taken as its protection layer. Plastic membrane's life shows 20 years, particularly under buried condition [10].

Concrete lining is the most common canal lining because of good control, small roughness, easy construction and long service life. The work was focused on reducing the cost, controlling the seepage, developing mechanical construction and frozen damage prevention techniques [10].

Among all these kinds of canal lining; membrane lining and concrete have the widest adaptability and have come the most important canal lining practices in China. Many factors affect life of plastic lining. Therefore a good maintenance program to assist in extending the life is adopted [10].

Finally Haushan conducted that; combination of membrane and lining not only greatly decreased the seepage rate but also alleviated the frozen heave damage. Polystyrene laminate is a good insulator to preserve the lining from frozen heave; and such practice showed that the results are convincing. Further study may switch to reducing its cost or developing other low cost insulator [10].

#### 3. Project (OFWM-I, II) Evaluation

The Water and Power Development Authority (WAPDA) commissioned for and evaluation of the World Bank Project indicated in its preliminary report [11] that copping intensity rose to about 2% - 5% and yield of rice, wheat and maize increased about 5% - 15% in chuck or command areas with renovated watercourses. The World Bank noted several deficiencies, which it felt should be addressed to the following areas;

Efficient translation of water saving into increased agricultural production.

Improved maintenance of renovated watercourses must be done by the Water User's Associations.

Emphases on board range of OFWM practices, especially at farm level. Improve processing of reimbursement applications of civil work sub-accounts. Proper project auditing by Government of Pakistan, and An improve watercourse evaluation program.

#### 3.1. Review of Achievements

An analysis of the country's economic situation indicates that Agricultural Production has grown at a fairly steady rate of about 4% per year and figures generated by the monitoring and evaluation program of WAPDA and Punjab Economic Research Institute (PERI) indicate the following benefits from watercourse improvement as: 1) Nearly 27% increase in water delivery efficiency, 2) About 53% saving of water losses, 3) 37% increased in cropped area, 4) 20% increased in cropping intensities, and 5) 24% increased in crop yield.

#### 3.2. Project Results

The monitoring program of World Bank found that watercourse renovation reduced water losses by 25% - 40%. Ninety five percent (95%) of the goal for the *accelerated watercourse lining and precision land leveling program* was realized.

#### 3.3. Sociological Benefits

Asian Development Bank Consultants, Graham Holt, confirmed that some of the major benefits were more sociological than economic one. "The farmer believe that he is more comfortable and that watercourse improvement has eliminated most of the disputes and litigation over water usage".

#### **3.4. Social Problems**

The common social problem of the unimproved watercourse is disputes over the alleged stealing of water from the head of watercourse.

One of the member of the Water Users Association (WUA) of MN56 watercourse estimated that farmers working on the earthen watercourse had killed averagely 40 snakes a day.

The major benefit of this improvement is that, it gave us the consciousness of our losses.

#### 4. Problems Associated with Canal/Watercourse Lining

**Figures A1-A5** (**Annexure-I**) show the earthen un-improved, earthen improved, unlined and lined portion of watercourses for canal water irrigation system. While in **Figure A6** is of Kacho Area (Hilly Area). From the interviewing and field visit, it is observed that there is no any irrigation system for crop cultivation, like drip or sprinkler irrigation. The soil of that area is sandy loam so the infiltration rate is high. The surface irrigation system is not feasible for this area.

It was enumerated that several problems which are associated with lining of canal/watercourse put adverse effects on the economy of the country, which is described as below; [12].

One of the major problems is defective construction that has cropped up from various reasons, such as: poor supervision, unqualified staff, obsolete construction technique, poor soil compaction, concrete compaction, concrete curing, poor control of concrete mixing.

The second problem is of Design Material, Defective Design and use of swelling soil. The canal ends larger than it needs to be, unsuitable material (using local cheep material of pit sand instead of hill sand).

The third problem is of Natural Causes, such as; penetration of roots, vegetation growth, animal damage, rodents, Crabs and other invertebrate holes in the canal banks.

The fourth problem is of Bad Maintenance, which involves the siltation, vegetation and masonry repair.

The fifth problem is of the Farmer's Interference, such as; illegal out lets (Turnouts) from minors/watercourses, water charges encourages wastage of water (Wasting the share water).

The sixth problem is the Pilferage that is "the theft of key materials such as cement, bricks etc. Which means that the construction quality suffers to the extent that concrete is too weak or too thin to do its job, and the structure falls down. This is common practice in *India* and *Pakistan*" [12].

#### Kacho Area (Hilly Area) of Sindh

It is clear from the **Table A1** (**Annexure-II**) describing that no mandatory work has been done under any of the Sindh Water Management Project as per highlighted Kacho Area (covering the hilly area of Jamshoro, Thatta and Karachi districts running along M-9 Motorway) in **Figure A7**. Sindh On Farm Water Management (SOFWM) Project had particularly worked on surface/canal water in other parts of Sindh province, while ignoring the groundwater resources at Hilly area of the said study site which is shown in **Figure A6**.

#### 5. Proposal Envisaged

From the above review, following suggestions are envisaged for better performance of the watercourse.

It is suggested that Fiber Glass type Plastic (cheap PVC) with semi-circular or U-shaped material in place of brick-mortar and concrete be used for watercourse lining, if market cost is compatible. As the climate of lower Sindh is semi-humid, this type of material is feasible for this zone. It is therefore proposed that experiments may be conducted to determine the cost-Benefit Ratio, Life Span and other related parameters. This methodology could accelerate the watercourse lining program, and could also help for development and encouraging the Petrochemical Industry.

There is enough capacity of sweet groundwater zones at Kacho Area (Hilly Area), so it is advised to develop a scientific approach to conserve the ground-water.

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#### **Conflicts of Interest**

The authors declare no conflicts of interest regarding the publication of this paper.

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#### **Annexure-I**



Figure A1. Earthen unimproved/Unlined watercourse having grasses.



Figure A2. Another view of earthen un-improved watercourse.



Figure A3. A portion of twin lined watercourse having grasses over berms.



Figure A4. Earthen improved watercourse, ready for lining.



Figure A5. A portion of Lined Watercourse needs rehabilitation.



**Figure A6.** Showing the Tube well water flowing for irrigation and drinking purposes and Al-Wardah Farm at Nooriabad. There is no any concrete structure or high efficiency system for irrigating the crops and orchards.





(b)

**Figure A7.** (a) Map of Sindh, Pakistan showing the Kacho Area (Hilly Area). (b) Showing the study area from Nooriabad to Karachi along M-9 Motorway, highlighting the tube wells exploiting the groundwater.

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**Annexure-II** 

			No. of Comulated		SOFWM		Total				NP	MI						
No.	Name of District	No. of W/Cs according to	Completed W/Cs under Previous													Total	SOFWMP Additional	SOFWMP (Comprehensiv
		Inventory	Schemes From 1977 to 1998	2004-2005	2005-2006	2006-2007		2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	-	Financing	2012-2015
1	Badin	5307	242	33	417	0	450	0	79	485	533	144	97	40	0	1378	258	30
2	Dadu	1364	196	4	203	9	213	8	33	296	330	144	15	38	45	606	0	24
3	Ghotki	2884	468	11	328	60	399	2	69	334	280	94	47	13	1	840	343	28
4	Hyderabad	420	115	6	39	4	52	2	13	99	38	16	11	6	9	161	0	15
5	Jacobabad	2089	107	1	65	24	06	0	20	137	180	12	42	23	33	506	0	25
9	Jamshoro	835	120	0	97	24	121	0	39	188	150	72	31	11	10	501	0	24
4	Kamber	3005	224	1	153	28	182	1	30	254	241	100	67	45	28	796	0	5
×	Karachi	1228	67	14	83	10	107	14	06	273	310	48	1	0	0	736	0	120
6	Kashmore	2259	86	1	95	4	100	0	34	172	188	106	23	36	14	573	0	0
10	Khairpur	3413	460	0	370	79	449	I	179	550	649	195	98	59	124	1855	205	11
11	Larkana	1702	132	2	95	11	108	1	51	171	195	68	75	64	54	679	0	9
12	MirpurKhas	1686	458	6	147	51	207	2	49	128	116	55	22	11	0	383	155	23
13	NawabShah	1445	781	28	109	1	138	0	12	92	16	42	20	13	12	282	0	5
14	N. Feroz	1338	706	2	69	16	87	2	14	79	70	32	19	14	21	251	0	13
15	Sanghar	2103	1191	12	142	21	175	1	21	169	212	54	16	11	4	488	120	2
16	Shikarpur	2082	270	4	148	8	160	2	122	325	350	66	55	71	45	1036	0	3
17	Sukkur	1552	299	6	133	4	143	9	47	272	208	78	21	15	20	667	41	0
18	T. AllahYar	479	124	0	32	13	45	2	13	57	70	30	16	15	21	224	0	1
19	T. M. Khan	2059	535	0	199	41	240	0	67	295	321	151	59	24	5	922	225	42
20	Tharparkar	1759	0	21	126	15	162	10	124	205	225	124	0	0	0	688	0	65
21	Thatta	5742	411	4	425	75	504	4	307	526	601	166	77	109	105	1898	0	108
22	Umerkot	1246	360	0	95	44	139	0	14	06	115	56	37	10	0	322	74	5
23	Matiari	702	182	16	64	4	84	2	10	33	0	0	0	0	0	45	0	8
24	Sujawal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grê	and Total	46699	7576	178	3634	543	4355	63	1437	5197	5473	1912	879	631	548	16140	1421	563