Remodeling of Kalri Baghar Feeder

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ABSTRACT

The shortage of irrigation water supplies and reduced water carrying capacity of KB (Kalri Baghar) Feeder require remodeling of the canal (an off-taking canal from right bank of Indus River at Kotri Barrage). The designed NSL (Normal Supply Level) capacity of KB feeder was 257 cumecs (9100 cusecs), but it has now maximum flow rate of 241 cumecs (8500 cusecs) due to damaged cross-section and silted normal flow area. In present condition only CCA (Culturable Command Area) needs 277 cumecs, and the requirement of water supply is additional. The hydraulic parameters are revised up to its potential and remodeled the canal using C^{++} simulation model based on Lacey's Method and FlowMaster Model. Using these models present discharge is enhanced 5, 10, and 20%, which revealed changes in hydraulic parameters of the canal. The total length of the canal is 5761 m (18,900 ft) in which there is 4% of stone pitching and concrete lining and rest of the channel is passing through sandy loam soil, rocks and coarse sand areas. The regime (stable earthen) channel cross-section is remodeled using Lacey's method. The stone and concrete lined section is redesigned by Manning's procedure using FlowMaster simulation model. It is required and feasible to modify water carrying capacity of the NSL of the channel by 20% as compared to current conditions.

Key Words: **Remodeling Canals, KB Feeder, Hydraulic Design Models.**

1. INTRODUCTION

The KB Feeder was constructed from 1950-1955 as a part of the Kotri Barrage Scheme. Except for a section of concrete lined part from Reduced Distance (RD=100ft) 26-34 the whole channel is excavated in the sandy loam soils of the Indus flood plain and designed as a regime channel. The tail of the canal is constructed through rocky hills with a concrete bed and grouted masonry sides.

The designed water supply of the canal was 257 cumecs. At present the maximum discharge capacity is less than 241 cumecs. However, the discharge is only achievable by holding the Kotri Barrage head pond above nominal operating level of RL (Reduced Level) 68. The canal has insufficient capacity to meet present and future needs and deteriorated in condition such that the security of supply

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has been severely affected.

The KB Feeder (Upper) flows into the Kinjhar Lake and again KB Feeder (Lower) offtakes from the Kinjhar Lake which is used for irrigation and water supply to KG (Kinjhar Gujjo) canal to Karachi Water Supply.

The Kinjhar Lake also known KB Lake has been formed by closing the natural depression between the hills by bounding this gape. The Kinjhar lake storage was copious and assured water supply to Karachi and for its industrial development. The Lake itself is subjected to progressive siltation precipitated from silt laden waters of the Indus River. The latest hydrographic survey of the Lake bed was performed by the WAPDA (Water and Power Development Authority) Pakistan, which indicates that the Lake has 44806 hectare-meter of useable storage capacity at full supply level of RL 54 [1-2].

The KB Feeder System has designed CCA of 143,310 hectares (Tables 1-3) and required discharge of at least 277 cumecs against the designed capacity of 257 cumecs which is now decreased to 241 cumecs. Since the present system has an inadequate capacity to supply the planned quantity of water for irrigation command together with the sanctioned allocation for the water supply, it is proposed to remodel the channel. The current discharge of KB feeder is 241 cumecs if it is increased by 20% that will make canal capable to carry 291 cumecs to meet present and future demands of water supplies and irrigation purposes.

The agricultural waste, industrial effluent from the industries of Kotri and Nooriabad and other contaminations caused by picnickers visiting the Keenjhar Lake, the only source of drinking water for millions of people of the districts of Thatta and Karachi, is already a matter of concern for environmentalists and health experts; and the recent torrential rains in southern Sindh have increased the contamination and the recent decision would bring more misfortunes. Karachi obtains some 80% of raw water for its potable and industrial use from the river Indus through KB Feeder System. The KB feeder is also known as Karachi canal off-takes from right side of Kotri Barrage from Indus River (Fig. 1), and the canal conditions at various locations are shown in Figs. 2-4.

2. HYDRAULIC MODELS FOR REMODELLING OF CANALS

TABLE 1. PERENNIAL CANAL WITH THE CULTIVATABLE COMMAND AREA OF K.B FEEDER (LOWER)

No.	Name of Canal Perennial	CCA Hectares
1.	IL Samki (Extension Jam Branch)	4296
2.	IR Halat (Extension Jam Branch)	5816
3.	Hala Minor	1416
4.	DW Jam	759
5.	Thatta Distry (Extension KB Feeder Lake)	6652
6.	Purandas	7874
7.	Khatain Left	3186
8.	Khatain Right	2550
9.	Khati Distry	21755
10.	Nasir Distry	4590
11.	OL Branch	78832
12.	Damani Distry	3318
13.	Chach Puricha	2266
	Total:	143310 Hectares

Hydraulic numerical models of irrigation canals are important tools to simulate actual canal performance and check its various designs. In Pakistan, models are applied only on two canals to verify their design and planned operation of Chashma Canal and PHLC (Pehoor High Level Canal) in Khyber Pakhtunkhwa of Pakistan.

Researchers have spent many years of work on different numerical models, which can simulate a real canal. The Task Committee on Irrigation Canal Systems Hydraulic Modeling established by ASCE (American Society of Civil Engineers) examined a number of the computer programs available for simulating open-channel flow (MODIS, DUFLOW, CANAL, CARIMA, and USM). Irrigation canals modeling is based on the same unsteady flow conditions as used in river modeling. However, the canal and irrigation environment present several unique simulation problems generally not counted in river modeling. Numerous other mathematical models to compute the water flows in open canals are available among others SIC PROFILE, FLOP, MIKE, and SOBEK. Among them, Mike II, DORC, SOBEK, ODIRMODUT can also be used for simulation of Sediment Transport [3].

3. MATERIALS AND METHOD

The data of KB feeder is collected from the field and

TABLE 2. NON PERENNIAL CANAL WITH THE CULTIVATABLE COMMAND AREA OF K.B FEEDER

No.	Name of Canal Perennial	CCA Hectares
1.	Jam Branch below Gujo	25005
2.	Sakro Branch	59974
3.	Narichach Branch	12949
	Total:	97928 Hectares

TABLE 3: PERENNIAL CANAL WITH THE CULTIVATABLE COMMAND AREA OF K.B FEEDER (UPPER)

No.	KB Feeder (Upper) Perennial	CCA Hectares
1.	Small Minor and District Water Courses	14547
2.	Sanda Distry (Extension Kalri Lake)	39861
	Total:	54408 Hectares

FIG. 1. OVERVIEW OF KB FEEDER OF TAKING FROM INDUS RIVER AT KOTRI BARRAGE (SOURCE: GOOGLE. MAP)

FIG. 2. SLIPPED (BROKEN) BANKS OF K.B. FEEDER AT RD.1

FIG. 3. CHANNEL OF KB FEEDER NEAR KOTRI BARRAGE RUNNING AT FULL SUPPLY

FIG. 4. STONE APRON AT THE BANK OF KB FEEDER SYSTEM NEAR HEAD REGULATOR

some of historical data is provided by Irrigation and Power Department Sindh, Pakistan. The hydraulic parameters are revised up to its potential and remodeled the canal using C++ simulation model and FlowMaster Model. The software is given by USA Government to the Irrigation and Power Department government of Sindh, Pakistan [1].

FlowMaster is relatively new model and it is a worldwide used to simulate fluid conduct systems, simply and accurately. FlowMaster model specifically is used to perform hydraulic calculations for open channels design.

3.1 Lacey's Methods for Regime Channel Design

According to Lacey's method, the width of a normal channel at bankfull flow is proportional to the root of the discharge. It is a very straightforward method that has been established by many authors. The equation hinges on the fact that the velocity at bankfull discharge is a sole function of the bed material. At bankfull discharge the average velocity is no longer a function of the discharge, as is assumed in regime theory. At discharges below bankfull level the stream velocity is a function of the discharge to the power 1/6 [4].

A channel excavated in alluvium is considered to be in regime, when it is stable physically and also maintained dynamic equilibrium between the forces generating and maintaining the channel cross-section and slope velocity equation for regime channel is given as:

$$V = CR^{1/2} \tag{1}$$

where C is Constant when the channel is perfect regime and silt grade, R is Hydraulic Radius, since silts grades of all area cannot necessary be the same and other factor as an index of departure of silt grade from the standard silt has been introduce. This factor or coefficient is called silt factor is denoted by "f" which is equal to the square of critical velocity ratio "m".

$$f = \left(\frac{V}{V_o}\right)^2 = m^2 \tag{2}$$

In regime channel where the silt is of standard grade, silt factor f is co-related in terms of mean silt diameter, d as:

$$f = 1.76\ d^{1/2} \tag{3}$$

Where d is mean silt diameter in mm, for lower Indus basin plane, and d is 0.53 mm [5].

Lacey gave two equations known as Lacey regime equations. They were proposed in f_{ps} unit which when converted to MKS units are as:

$$V = 0.639\sqrt{fR} \tag{4}$$

and

$$Af^2 = 121.24V^5 \tag{5}$$

Where V is mean regime velocity; A is area of the channel section, and f is silt factor.

The first equation is applicable to perfect regime channel flowing in standard silt. Later he proposed a velocity equation applicable to every type of regime alluvial channel as:

$$V = 10.8\ R^{2/3}\ S^{1/3} \tag{6}$$

The above equations are fundament regime equations which are applicable to all regime alluvial channels from fine silt to boulders. Later a large number of relationships have been derived algebraically using the above basic equations. The derived relationships are useful in the design of irrigation channel.

3.2 Velocity Equation for Lined or Non-Regime Channels

In case of channels, which are not imperfect regime or in other words postulating between the initial and final regime, the velocity equation for lined channel is given by Manning as:

$$V = \frac{1}{N_a} R^{3/4} S^{1/2} \tag{7}$$

In Equation (7), N_a is Coefficient of absolute rugosity, which is defined as coefficient of rugosity N of Kutter (for regime channel) or coefficient of roughness of Manning (for lined channel) when the hydraulic radius (R) in meter. In terms of critical velocity ratio of silt factor f, can be written as:

$$N_a = 0.0225m^{1/2} \tag{8}$$

or

$$N_a = 0.0225f^{1/2} \tag{9}$$

The silt factor in terms of R and S can be expressed as:

$$f = 291.62\,(R^{1/2}\,S)^{2/3} \tag{10}$$

Equation (10) is useful in computing a working silt factor. While the Equation (10) is applicable well for regime as well as non-regime channels, the Equation (11):

$$f = m^2 = \frac{5}{2}.\frac{V^2}{R} \tag{11}$$

3.3 Hydraulic Design of Earthen Canals

The design of a canal primarily involves the determinations of adequate dimensions of the canal prism and its slope to enable it to safely and adequately perform its basic function of transporting water [5-8].

The procedures for designing involve the following:

(a) Selections of Lacey's silt factor.

(b) Determinations of various design parameters of water flow cross-section of the channel.

3.4 Selections of Silt Factor

Lacey's silt factor "f" is considered to cover all consideration of equality, shape, materials and size of silt. There are two types of silt factors, i.e. f_{vr} and f_{rs}. The silt factor f_{vr} depends on the silt concentration and the channel flow, while the silt factor f_{rs} is the function of the bed martial size. In the Lacey's equations the hydraulic slope and the capacity of canal to transport bed load is determine by f_{vr}, whereas the silt factor frs determines the capacity of the canal to transport the bed load and since it is always equal to or grater then f_{vr} it follows that f_{rs} governs the design. Therefore, the silt factor adapted design should be the value of f_{rs} and not f_{vr} for a canal with a given discharge, a large error in the value of f_{rs} would render the design unworkable whereas a similar error in the f_{vr} will not have any significant effect.

4. RESULTS AND DISCUSSION

4.1 Remodeling of Earthen Section of the Channel

The KB feeders present cross-section for 241 cumecs discharge is designed as a regime alluvial channel by Lacey's method (for non-scouring non-silting velocity) using the model. The cross-section is remodeled for increasing flowing capacity by 5, 10 and 20% for 255, 267 and 292 cumecs respectively. The corresponding changes in hydraulic design parameters are observed. It has been seen that flowing depth and channel bottom width are increased by average of 3%. The velocity of flow is increases 5% for present channel condition to 20% increase in discharge. There is no significant change appears in channel bottom slope (0.000166) and side slopes (H:V=1/2: 1). The results of present channel cross-section and 5, 10 and 20% enhanced in flowing capacity are shown in Table 4, Figs. 5-8.

4.2 Remodeling of Lined Channel Section

The KB Feeders has 300m concrete lined section which is remodeled by increasing flowing capacity 5, 10, and 20% and corresponding hydraulic design parameters are studied. In the lined section we can increase velocity of flow and reduce the channel cross-section. In this case the velocity of flow is increased 1.49-1.58 m/s from present to 20% increase in discharge. However, in alluvial channel section velocity of flow was 1.06 m/s. The flow depth and bottom width of the channel is recomputed by Manning's channel design which is determined current to maximum observed is 2.75-3m, and 58-60m (3% average increase) respectively. However, there is no prominent change observed in channel bottom slope (0.000165) and side slopes (H:V=1/2: 1). The findings of present channel cross-section and 5, 10 and 20% modified in flowing capacity are given in Table 5, and shown in Figs. 9-12.

5. CONCLUSION AND RECOMMENDATIONS

The numerical simulation models are decision support systems for channel redesigning and to study their potential fact to offer extensive range of functional developments. After going through the result it has been concluded that KB feeder channel cross-section can feasibly be enhanced for 20% increase in its water carrying capacity. Whereas

TABLE 4. REDESIGNING OF THE CHANNEL DESIGN BY LECYES'S METHOD USING KUTTER'S COEFFICIENT N = 0.026

Parameters	Current Condition	5% Increase in Discharge	10% Increase in Discharge	20% Increase in Discharge
Discharge (m^3/s)	240.80	255.15	267.30	291.60
Channel Slope (m/m)	0.000165	0.000166	0.000156	0.000164
Channel Depth (m)	3.25	3.30	3.40	3.50
Left Side Slope (H:V)	0.50	0.50	0.50	0.50
Right Side Slope (H:V)	0.50	0.50	0.50	0.50
Bottom Width (m)	68.00	70.00	72.00	73.00
Flow Area (m^2)	226.28	236.45	250.58	261.63
Wetted Perimeter (m)	75.27	77.38	79.60	80.83
Top Width (m)	71.25	73.30	75.40	76.50
Critical Depth (m)	1.08	1.10	1.12	1.17
Critical Slope (m/m)	0.006629	0.006580	00.006547	0.006438
Velocity (m/s)	1.06	1.108	1.07	1.11
Velocity Head (m)	0.06	0.06	0.06	0.06
Specific Energy (m)	3.31	3.36	3.46	3.56
Froude Number	0.19	0.19	0.19	0.19

FIG .5. CROSS-SECTION OF KB FEEDER FLOW AREA IN PRESENT CONDITION

FIG .6. REDESIGNED CROSS-SECTION OF KB FEEDER FLOW AREA BY 5% INCREASE IN DISCHARGE

FIG. 7. REDESIGNED CROSS-SECTION OF KB FEEDER FLOW AREA IN BY 10% INCREASE IN DISCHARGE

FIG 8. REDESIGNED CROSS-SECTION OF KB FEEDER FLOW AREA IN BY 20% INCREASE IN DISCHARGE

by applying the computer models, setting up of models required some adjustments to match the requirements of local situation. It is recommended that water carrying capacity at present needed at least 280 cumecs, which may be increased by 300 cumecs, without going non-potential and economical expenses.

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TABLE 5. REDESIGNING OF THE CHANNEL DESIGN BY MANNING'S METHOD USING MANNING'S COEFFICIENT N = 0.016

Parameters	Current Condition	5% Increase in Discharge	10% Increase in Discharge	20% Increase in Discharge
Discharge (m3/s)	240.80	255.15	267.30	291.60
Channel slope (m/m)	0.000165	0.000166	0.000156	0.000164
Channel Depth (m)	2.75	2.80	2.90	3.00
Left side Slope (H:V)	0.50	0.50	0.50	0.50
Right side Slope (H:V)	0.50	0.50	0.50	0.50
Bottom Width (m)	58.00	58.60	59.75	60.13
Flow area (m2)	163.28	168.00	177.49	184.88
Wetted Perimeter (m)	64.15	64.40	66.24	66.84
Top Width (m)	60.75	61.40	62.65	63.13
Critical Depth (m)	1.20	1.24	1.26	1.33
Critical Slope (m/m)	0.002522	0.002425	0.002410	0.002371
Velocity (m/s)	1.47	1.52	1.51	1.58
Velocity Head (m)	0.11	0.12	0.12	0.13
Specific Energy (m)	2.86	2.92	3.02	3.13
Froude Number	0.29	0.29	0.29	0.29

FIG .9. CROSS-SECTION OF KB FEEDER FLOW AREA IN PRESENT CONDITION

FIG. 10. REDESIGNED CROSS-SECTION OF KB FEEDER FLOW AREA IN BY 5% INCREASE IN DISCHARGE

FIG. 11. REDESIGNED CROSS-SECTION OF KB FEEDER FLOW AREA IN BY 10% INCREASE IN DISCHARGE

FIG. 12. REDESIGNED CROSS-SECTION OF KB FEEDER FLOW AREA IN BY 20% INCREASE IN DISCHARGE

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