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Use of the SETRIC Model for Examining the Functioning of an Irrigation Canal Carrying Sediment-laden Water

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Abstract: Agriculture is vibrant for the economy of many countries worldwide. Optimal performance in terms of reliability, efficiency, and adequacy of the irrigation system plays an important role in the economic uplift of a country. Sediment accumulation in a canal significantly affects its morphology as well as the water supply for agriculture. This study comprises the application of a numerical model to study this highly important and challenging issue of the sediment transport process in Upper Chenab Canal (UCC), Pakistan. The SETRIC model has been applied to investigate the sediment transport in UCC. Manning's formula is used to deal with the roughness in governing equations. The Ackers and White equation is adopted for estimating the sediment load. Data regarding the discharge, sediment concentration, gradation curve for sediment, and geometry of the canal were collected from Marala Head Office, Sialkot. The condition of the canal, for which the data has been collected, was investigated, and found that its performance is not optimal. Outlets of the upper reach of the canal draw more water, whereas the delivery performance ratio (DPR) of the tail outlets is not up to the mark. The model has been applied to determine the non-silting and non-scouring concentration of sediment flows through a hit-and-miss approach until the DPR values of the outlets at the upper and tail reaches of the canal converge, indicating uniform supply. Canal efficiency can further be improved by allowing non-silting and non-scouring sediment. The results of this study will be highly useful for canal operation and management.

Keywords: Suspended Sediments, Discharge, Canal Cross Sections, DPR, Bed Level

1. INTRODUCTION

Water, energy, and food nexus components are highly important research topics as these are directly related to the comfort and uplift of human beings [1, 2]. The growing water crisis in irrigated agricultural areas serves as a dire warning for food security [3, 4, 5]. According to [3], about 84 % of households in the irrigation scheme of Burkina Faso only suffer from monetary insecurity, and around 38 % from weak food security. Irrigated agriculture is among the top critical issues. In addition to several serious concerns, sediments in canal flows cause severe impacts on irrigation [6]. This has been seen as a matter of dominance because of the presence of highly variant geological formations lying at the origin of all the tributaries of the canal system in many countries [7]. Whereas sediments in canal flows cause many serious impacts on irrigation. It has been noticed that each tributary has a set of its unique characteristics and requires detailed study for the comprehension of the flow behavior.

Sediment transport is a complex type of flow [8, 9]. Only a few studies have investigated this issue for canals. It is still a demanding and challenging issue. There are changes in bed morphology that have an impact on the performance of the irrigation system [10]. The first step in sediment flow modeling for irrigation canals is to select flow resistance and sediment load estimation equations. A lot of literature is available for flow resistance formulae, and Manning's equation is most commonly used for this purpose. Various empirical and semi-empirical models have been developed during the past century for sediment load estimation; however, a universal model for various types of channels has remained difficult to achieve to date [11, 12, 13]. In addition to this difficult task, several other factors influence the canal modeling, the main goal of which is to improve productivity and water efficiency with improved operations of the water supply, optimal management of irrigation systems, and improvement in the farmer's working conditions [14, 15]. The productivity of an irrigation scheme is influenced by the mode of transportation of water, the canal condition, and the technology of irrigation [16]. Poor maintenance of the canal results in ineffective supply of water to the crops (Siyal et al. 2021, Siyal et al. 2023) [16, 15]. A new method has been investigated to provide the underpinning science for water security management, immediately required by the world [17]. Some researchers [18, 19, 20] studied the impact of technology used in the irrigation sector on the economic and financial performance of irrigated fields in Zimbabwe. Non-linear models have been used to study the cropping patterns and schedule of irrigation water by some researchers [21, 22, 23]. Climate change impacts on irrigation scheduling have been studied by [24]. Flow features and morphological alterations, which are mainly related to flows in open channels with different vegetation zones were examined by [25, 26]. Sedimentation and erosion of irrigation canals is a severe threat in major parts of the world. This aspect of canal irrigation requires a lot of further research work.

Numerical models solve the governing equations of sediment transport, which are mainly partial differential equations. These models are one-dimensional, two-dimensional, and three-dimensional [27]. The complexity of modeling varies from three-dimensional, which are highly complex, to one-dimensional, which are comparatively lower in complexity [28, 8]. There are several types of complexities in sediment transport modeling. Three types of problems are faced in such modelling studies, including the solution of governing equations, the choice of roughness parameters of frictional equations, and parameters of sediment load equations. The parameters of sediment load equations have been investigated by [29] in detail, and recently, [8] examined the impact of bedforms, including silt ripples on the roughness offered by the bed of the channel. Both have urged further research in this context. Although sediment transport in canals is a three-dimensional phenomenon, the well-defined cross-sections of the canals mean that one-dimensional models may provide acceptable results. Hence one-dimensional model SETRIC has been chosen in this study to solve the Saint Venant equations. Manning's equation for roughness and Ackers and White's equation for sediment load have been selected as supplementary equations.

The sediment transported by the globally famous Indus River has three origins: the catchment area, riverbanks, and its bed. This makes the sediment flows highly complicated. The Indus River is a dynamic one because its behavior changes spatially as well as temporally. So, each canal taken off from this river has unique sediment characteristics. The sediment amounts of the Himalayan Rivers are substantially higher than the sediment loads of other mountainous territories worldwide. If hydraulic structures like barrages and dams had not been there, the main rivers of the Indus basin would have carried a total sediment of 1.2 Giga Tons/year to the sea [30]. The Indus River transports about 200 million tons annually into the Tarbela reservoir and about 330 million tons annually at Kotri [30]. These facts always attract engineers and scientists to research the sediment transport of canals in Pakistan. The present paper has chosen a very important canal, namely the Upper Chenab Canal. The main objective of the manuscript is to investigate the sediment transport in the canal using numerical modeling. Many aspects of canal irrigation have been studied, but according to the literature reviewed by the authors, very little work has been done on the sediment transport of this canal, which makes the present research original and novel.

2. MATERIALS AND METHODS

2.1 Methodology Framework

The main methodology is briefly described in the framework given in Figure 1. The first step involves data collection, which is of two types, including hydraulic and geoinformatics records. Both types of data have been collected from the Irrigation Department, Lahore, and the Marala Headworks Office. Discharge hydrographs, depth of flow, water levels, sediment concentration, mean sediment diameter, and roughness parameters have been collected as hydraulic data. The lateral and longitudinal cross-sections of the canal have been obtained from relevant offices. The bed slope of the canal has been estimated from the geometric data. The second step comprises calibration and validation of the SETRIC model and comparison of its results with those of the SIC model. At the end, the calibrated and validated model has been used to investigate the performance of the canal under various scenarios of sediment transport.

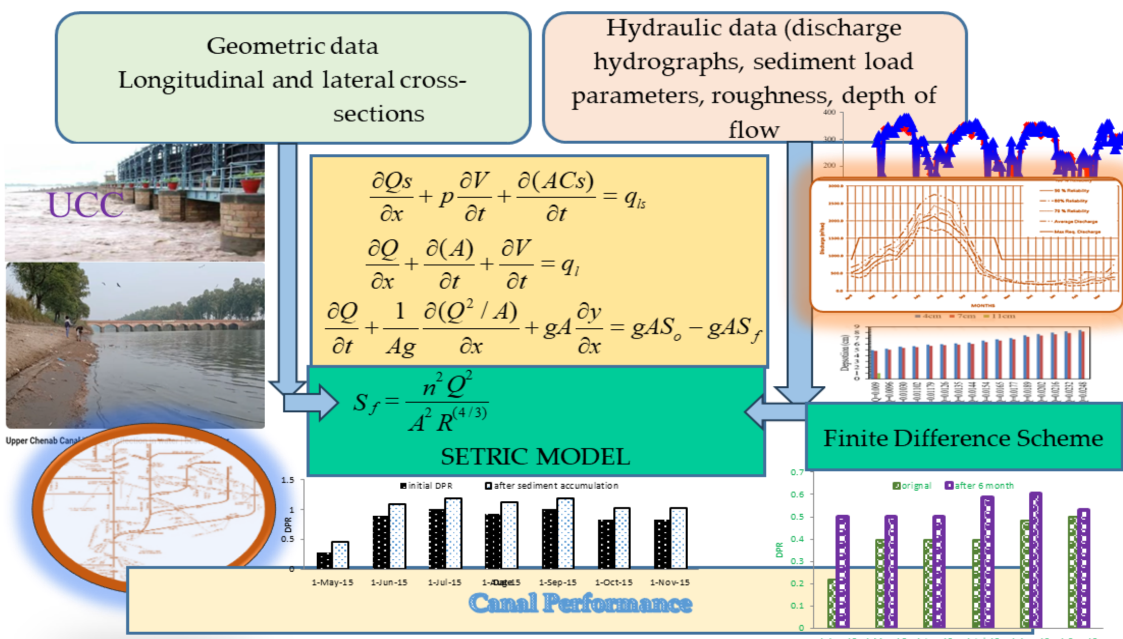


Figure 1: Methodology framework

2.2 Canal Under Study

As stated in the previous section, the data regarding water discharge Q, sediment discharge Q_s, longitudinal profiles containing cross sections and bed levels detail were collected from different departments. The study is performed on Upper Chenab Canal (UCC), which takes off from Marala Barrage, the red color area shown in Figure 2a represents the study area. UCC is a large canal having a base width of 97 m and side slopes of 0.5:1 as shown by Figures 2 b&c. The mathematical model used in the study, which is SETRIC, was initially calibrated, validated, and then used to simulate the flow of the canal as well as the sediment behavior in the canal. The other major features regarding the canal under study are given in Table 1 and Figure 2 (a, b & c).

Table 1: Main features of UCC

Channel type	Main canal	Tail discharge (m^3/s)	322
Length (km)	43	Gross command area (Hectares)	7938
RD	133296	Culturable command area (Hectares)	5042
Head discharge (m^3/s)	528	Flow type	Perennial

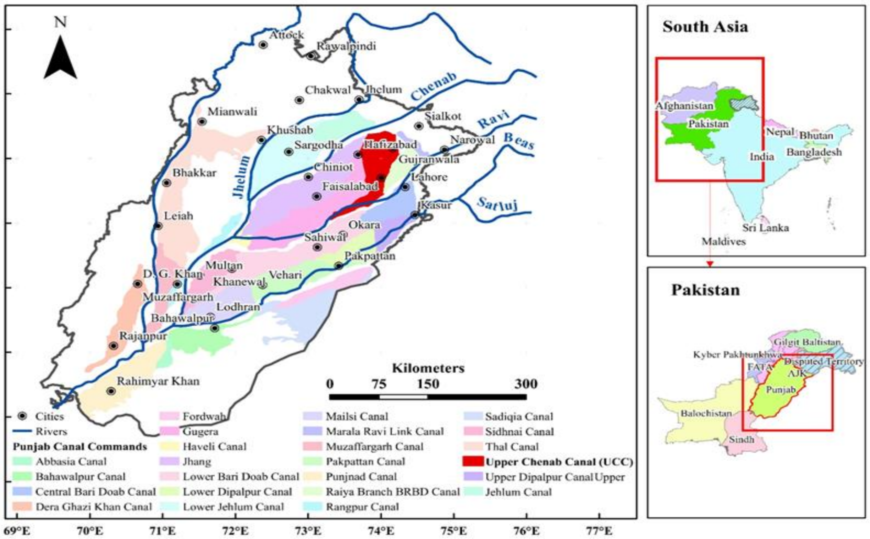
Input data related to bed levels, bed roughness, and longitudinal slope are used for the simulation of sediment transport behavior in the canal. Parameters used for the model are described in Table 2. Upper Chenab Canal has a length of 43 km with a full discharge capacity of 528 m^3/s.

Table 2: Sediment features of Upper Chenab Canal

Specific gravity of sediments	**2.65**	Gravitational acceleration (g) (m/s^2)	**9.81**
Mean sediment diameter (m)	0.000399	Flow depth (d) (m)	4

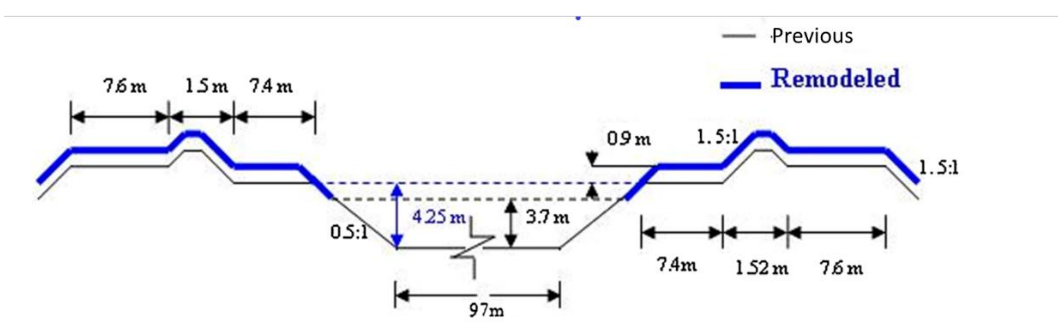
2.3 Governing Equations and SETRIC Model

The above equations 1 to 3 can be solved by methods that can be divided into several types. The term ∂V/∂t in these equations represents the rate of change of bed levels. If it is ignored from the flow continuity equation 2, the sediment continuity equation 1 is uncoupled from equations 2 and 3. Still, there is coupling through the bed slope and frictional relationships. So, there are two main categories of sediment transport models, namely, coupled and uncoupled. In the uncoupled solution, equations 2 and 3 are solved for discharge or velocity and area of flow or depth, followed by a separate solution of equation 1 to find the volume of sediment. In a fully coupled solution, equations 1 to 3 are solved simultaneously to yield discharge or velocity, area of flow or depth, and the volume of sediment per unit length. However, uncoupled solutions are not capable of satisfying arbitrary boundary conditions, such as constant stage. The model SETRIC is an uncoupled type of model used in this study.



a)

b)



c)

Figure 2: Canal under study, UCC (Upper Chenab Canal); a) Map of Irrigation System of Punjab, b) Inlet of UCC c) Cross-section of UCC.

Flow in canals can be considered as one-dimensional for practical purposes as far as the water supply and demand is concerned. The one-dimensional unsteady flow can be described by Saint-Venant's partial differential equations for continuity and momentum as follows:

$$\frac{\partial \mathrm{Qs}}{\partial x} + p\frac{\partial V}{\partial t} + \frac{\partial (\mathrm{ACs})}{\partial t} = q_{\mathrm{ls}} \ (1)$$

$$\frac{\partial Q}{\partial x} + \frac{\partial (A)}{\partial t} + \frac{\partial V}{\partial t} = q_l \ (2)$$

$$\frac{\partial Q}{\partial t} + \frac{1}{\mathrm{Ag}}\frac{\partial (Q^2/A)}{\partial x} + \mathrm{gA}\frac{\partial y}{\partial x} = \mathrm{gAS}_o - \mathrm{gAS}_f \ (3)$$

Where, Q is discharge, A is area of flow, V is volume of sediment deposited/eroded per unit length of channel, x is distance along the channel; t is time; q_l is lateral flow; g is acceleration due to gravity; T is channel top width; S_o is bed slope, S_f is friction slope, Q_s is sediment discharge, C_s is Q_s/Q is the sediment concentration, p is the volume of sediment in unit volume of bed layer and q_{ls} represents the lateral sediment flow.

The equations 1 to 3 require two additional equations to solve. One equation is needed for the estimation of frictional slope S_f, and the second equation is necessary for the sediment discharge Q_s

The above-mentioned S_f, the frictional slope, can be determined by Manning's equation, i.e.:

$$S_f = \frac{n^2 Q^2}{A^2 R^{(4/3)}} \ (4)$$

Where n denotes the Manning's constant, and R represents the hydraulic radius.

2.4 Ackers and White Formula for Total Sediment Load

The Acker and White's equation, developed long ago in 1973, is commonly used for predicting sediment concentration in canal flow [29]. The equation needs the various steps to estimate the total sediment concentration.

The dimensionless particle size parameter is calculated as:

$$\boldsymbol{D}_{*\,(gr)} = \boldsymbol{d}_{50}\left(\frac{\boldsymbol{g}(\boldsymbol{s}-\mathbf{1})}{\boldsymbol{\nu}^2}\right)^{(\frac{1}{3})} \ (\mathbf{5})$$

Here, ($D_{*(gr)}$ is dimensionless-sediment-diameter, d_{50} is particle diameter of sediments, g is gravitational acceleration, s is specific gravity of sediments, and ν is the kinematic viscosity of water.

For course sediments, some parameters n, A, m, and C can be taken as: n = 0.0, A = 0.17, m = 1.5, C = 0.025

If $Dia_{(gr)}$is less than 60 but larger than 1, the sediments are medium-sized, and the values of n, A, m, and C can be estimated by the equations given below.

$$n = 1.0 - 0.56 \log D_{*(gr)}$$

$$\boldsymbol{A} = \frac{\mathbf{25}}{\sqrt{\boldsymbol{D}_{*\,(gr)} + \mathbf{0.14}}} \qquad (\mathbf{6})$$

$$m = \frac{9.66}{D* \quad (gr) + 1.34} \tag{7}$$

LogC = 2.86 log($\boldsymbol{D*} \quad _{(\boldsymbol{gr})}$) – (log($\boldsymbol{D*} \quad _{(\boldsymbol{gr})}$))^2 – 3.53

The Mobility number is given as:

$$MN_{gr} = \frac{u^n}{\sqrt{gd\left(\frac{\rho_s - \rho_w}{\rho_w}\right)}} \left[\frac{V}{\sqrt{32}log\left(\frac{10D}{d_{50}}\right)}\right]^{1-n} \tag{8}$$

In the above equation, MN_{gr} is the mobility number, V is the flow velocity, u *is shear velocity, n: Acker and White coefficient,* p_s*: density of sediment,* p_w*: density of water, d: mean water depth, and D: water depth.*

Sediment concentration (PPM) is given as:

$$c = \frac{\left(\frac{\rho_s - \rho_w}{\rho_w}\right)}{D} C \left(\frac{MN_{gr}}{A} - 1\right)^m \left(\frac{V}{u}\right)^n \tag{9}$$

The most important reason for choosing the SETRIC model in this manuscript is its simplicity of application and availability with acceptable accuracy of results. The model is user-friendly and easily available. It is freely available from the University of Engineering and Technology, Taxila, Pakistan. The 2-D and 3-D models are highly complicated and need very extensive data, which is not only difficult to obtain but is very expensive as well. The main question is of accuracy of the results. The flow in canals is mostly of a two-dimensional type, except for that of the sediments, which are three-dimensional. However, this difficulty is also minimized by the regular cross-section of canals different than the natural channels and rivers, where three-dimensional models provide better accuracy of results. Hence, the SETRIC model can be used for canals without losing too much accuracy.

2.5 Calibration and validation of the SETRIC Model

Calibration of models is important for the validity of any model. For calibration of the SETRIC model, the data regarding water levels is used with actual canal conditions, and parameters are optimized till the error between the simulated and actual water levels is minimized. After calibration of the model with six months of data, the model was validated for another six-month period to calculate the real efficiency of the model. During this period, the canal water level obtained from the hydrological survey conducted by the irrigation department was analyzed, and a comparative analysis was made to test the model's validation.

The performance parameters of models, including Nash-Sutcliffe Efficiency (NSE) and root mean square error (RMSE) are given as [29]:

$$NSE = \left(1 - \frac{\sum_{i=1}^{n}(WL_{oi} - WL_{si})^2}{\sum_{i=1}^{j}(WL_{oi} - \overline{WL}_{oi})^2}\right) \tag{10}$$

$$RMSE = \left(\frac{\sum_{i=1}^{n}(WL_{oi} - WL_{si})^2}{n}\right)^{\left(\frac{1}{2}\right)} \tag{11}$$

Where "WL" is the water level and n is the total number of data points along the channel.

It is worth mentioning that most of the canals have a closure period annually or every six months during which maintenance, repair to the structure, and sediment removal actions are performed. Hence, 6-monthly data was used in this study for calibration and validation of the model. The parameters of the Ackers and White equation and the Manning's roughness coefficient were adjusted to obtain the minimum possible values of RMSE and the highest values of NSE. Sensitivity analysis and guidelines provided by [30] have also been used in this manuscript.

2.6 Canal Performance

The performance of a canal is usually measured in terms of delivery performance ratio (DPR), Equity, efficiency, and similar statistical performance indicators. In this manuscript, DPR and equity have been used to describe the performance of UCC. DPR is the ratio of actual outlet head to the design head of the outlet. The equity represents the difference in DRP for various canal outlets. Ideally, the DPR should equal to 1.0, and for equity, it should be the same for all head, middle, and tail outlets.

3. RESULTS AND DISCUSSION

3.1 Model Calibration and Validation Results

The closely matching measured water levels and simulations from the model are represented in Figure 3(a, b & c) for calibration and validation of the model. It is observed that the difference between the simulated and measured water levels is negligible both in calibration and the model (maximum error in water levels is 0.18 m only). For further validation, the model was compared with the SIC model. SIC represents "Simulation of Irrigation Canals" which is also a sediment-laden flow model used in water resources development, planning, and management. SIC focuses on simulating flow and sediment transport in irrigation canals, including equilibrium and non-equilibrium conditions. Both of these models are applied for analyzing and managing sediment transport in irrigation canals. It is found in this research that both the models produce very close results (the maximum difference in water levels simulated by the SIC and SETRIC models are 0.23 m, which is considered to be a minute difference. The values of NSE were found to be 0.976 and 0.99 for calibration and validation, respectively. The RMSE was 0.33 and 0.21 for calibration and validation, respectively.

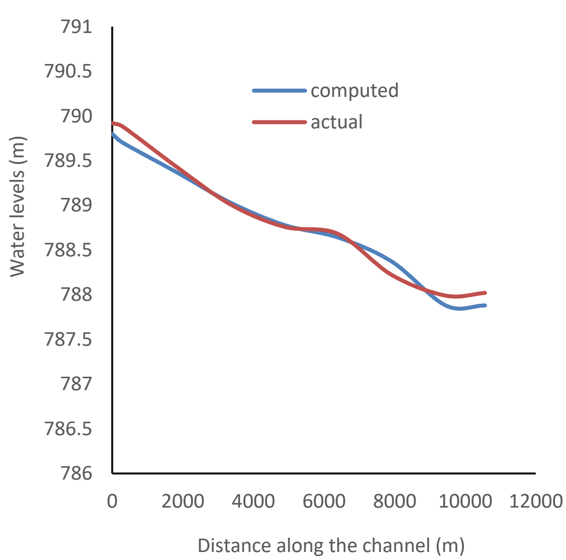


Figure 3a: Model calibration results

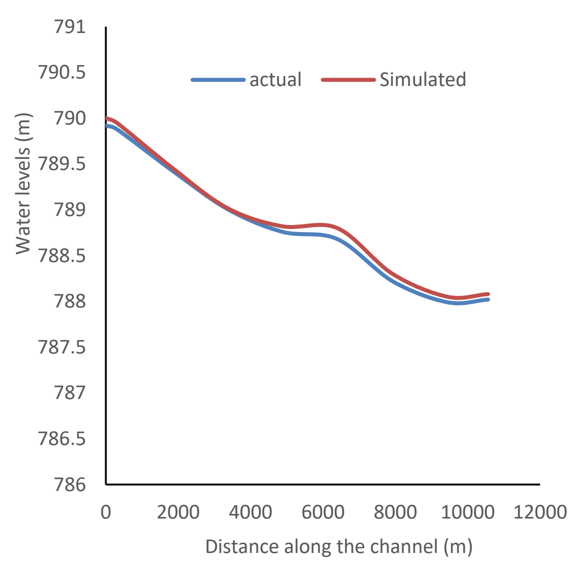


Figure 3b: Model validation results

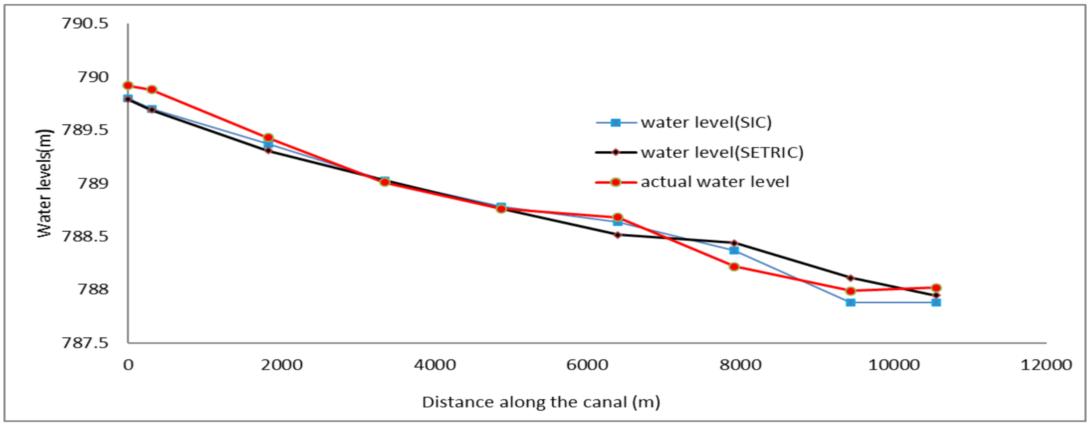


Figure 3c: Results of comparison of SETRIC model with SIC model

3.2 Bed Level Changes Due to Sediment Concentration

After calibration and validation of the model, model simulations have been obtained for different values of silt concentrations. The results of such simulations are shown in Figure 4. The average concentration in UCC was found to be 300 ppm. Whereas the maximum concentration of sediment was recorded to be 730 ppm in the month of September. Negligible small change in bed levels was recorded in UCC by varying sediment concentration from 0 to 130 ppm. However, at and over 138 ppm, some changes in bed levels were observed. Bed levels significantly change for sediment concentration over 200 ppm. Sediment accumulation was noticed in the bed of the canal at about 2000 m from the head of the canal for a sediment concentration of 300 ppm.

Bed level changes were found to be maximum for a sediment concentration of 730 ppm in the Upper Chenab Canal, which enters the canal during August and September due to the flooding season.

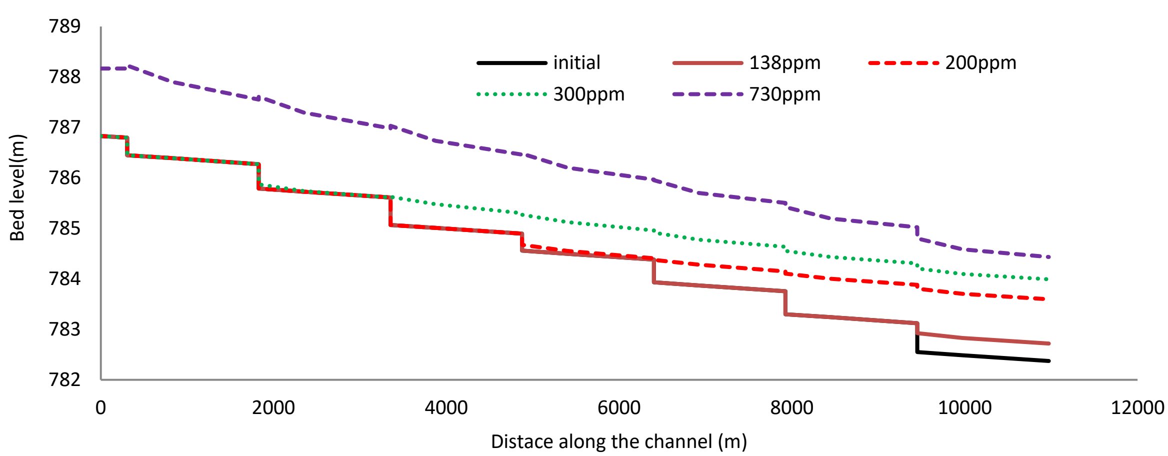


Figure 4: Bed level change due to different sediment concentration

In this hit-and-trial procedure for different concentrations of silt, an amount of sediment concentration that is responsible for non-silting non non-scouring bed was found to be equal to or less than 130 ppm, at which the bed levels suffer no changes with respect to time and remain as designed.

3.3 Sediment Volume Accumulated in Canal

Sediment volume increases with increasing concentration. At 138 ppm, the volume of sediment accumulated on the bed of the canal is comparatively less than that of 300 ppm. When the model was run for a period of 180 days (mid-year; 6 months after which usually the maintenance/Bhal Safai of the canal can be requested, other than annual closure), the amount of sediment volume accumulated was simulated to be 803862.97 m^3. Sediment volume trapped in September is 3315078.74 $m^{3,}$ as shown in Figure 5, which is for the maximum sediment concentration of 730 ppm. Sediment accumulated after 2 years was computed to be 90% more than the previous year. Sediment accumulated in different years in the canal is shown in Figure 6. However, every year, there is a closure of the canal twice or at least once for some period. During this closure, the main task is the removal of sediment deposits (Bhal Safai), repair of banks, repair of hydraulic structures if there is any damage, and other maintenance works.

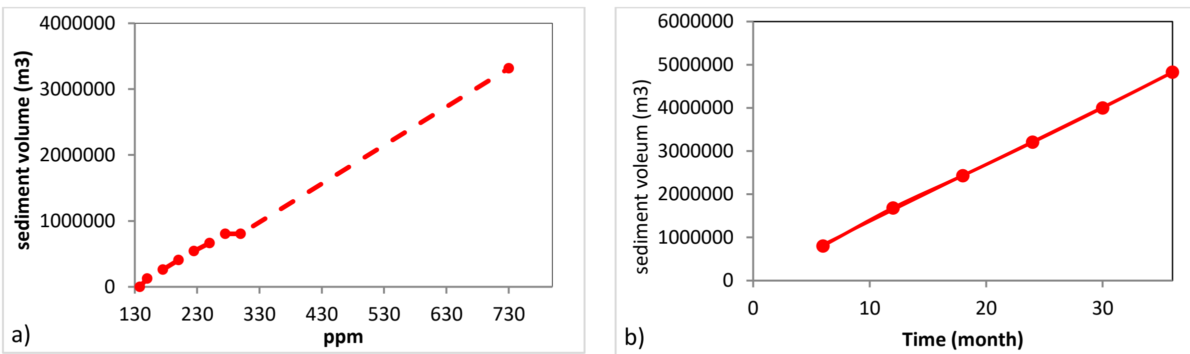


Figure 5: (a & b): Sediment volume; a) Sediment volume vs ppm in canal, b: Sediment volume vs time in canal

3.4 Effect of Sediments on the Performance of the Canal

As stated above, the canal performance is measured in terms of DPR in this manuscript. The DPR of three essential branches of UCC, including Bambanwala-Ravi-Baidia-Depalpur (BRBD), Nokhar, and Main Line Lower (MLL) is given in Fig. 6(a & b) and Table 3. These three branches represent the head (BRBD), middle (Nokhar), and tail (MLL) branches of UCC. It is observed that the DPR of all three branches is less than one, showing that the performance of the canal is not up to the mark. It should be close to 1.0 for an ideal situation, but the actual DPR ranges from 0.72 to 0.48 (Fig. 6a). There are several reasons for not obtaining a high DPR. One of these reasons is the sediment deposition on the bed of the canal. Sediment accumulation in the canal affects its DPR due to variation in its cross-sectional area. Bed level rises and discharge capacity decreases for the canal. DPR variation is more for outlets in the upper reaches (head reaches) of the canal, and its value becomes comparatively less for outlets in the tail reaches of the canal. Due to this variation, the outlet at the head reach of the canal draws more water, whereas the tail outlets draw less supply. So, there are usually water shortage problems at the tail reaches of the canal. If a controlled structure is not provided to regulate water, then the rise in bed level due to sediment deposits enhances the discharge extracted by the canal outlets, which results in increased DPR. The DPR of different UCC outlets is analyzed in relation to the rise in bed level and the increase in discharge. Comparative sediment accumulation increases with distance due to the rise in bed shear and low discharge. Hence, controlling sediment concentration and allowing non-silting non-scouring sediment transport, the DPR of the canal is expected to be partially improved.

For the model runs under non-silting non-scouring conditions, there is a slight improvement in the canal performance. The DPR at the head, middle, and tail outlets becomes very close to one another (Figure 6b). There is a difference of only 0.03 to 0.06, which is negligibly small. However, the performance of the canal remains lower than the design values.

Several years ago, development in irrigation began in various regions, including Ethiopia, India, and Pakistan, but the effectiveness of the developing schemes remained very small. There are multiple factors, including general-physical, structural, availability of sufficient discharge, irrigation methods, and social factors, affecting the performance of irrigation canals. Damaging to the irrigation structure due to sedimentation or scouring, and a lack of participatory actions in scheme growth are the most common elements of irrigation system performance. So, development of the catchment and participation of the community in irrigation system development are vital for vindicating the underperformance of canals. Hence, in addition to controlling sediment, other development actions are recommended for improving the performance of the canal.

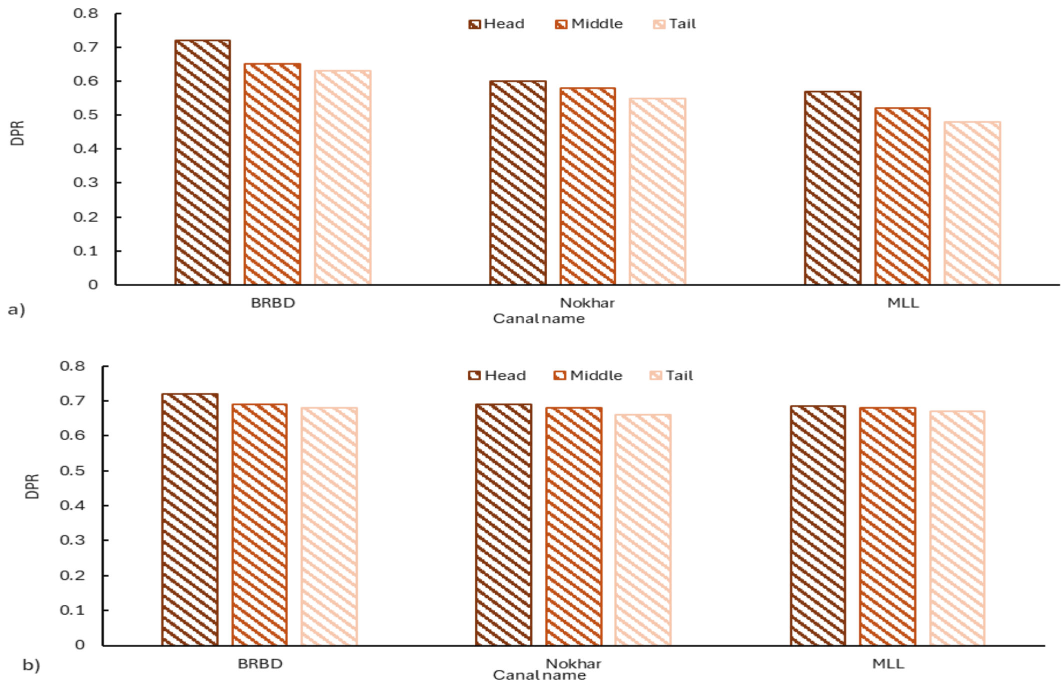


Figure 6 (a & b): Variation in DPR based on average sediment concentration. a) Actual prevailing conditions, b) Non-silting non-scouring conditions

Table 3: DPR values for various sediment concentration conditions

Location	DPR of BRBD			DPR of Nokhar			DPR of MLL		
	Prevailing condition	Non-silting non-scouring condition	Difference	Prevailing condition	Non-silting non-scouring condition	Difference	Prevailing condition	Non-silting non-scouring condition	Difference
Head	0.72	0.72	0	0.6	0.69	-0.09	0.57	0.685	-0.115
Middle	0.65	0.69	-0.04	0.58	0.68	-0.1	0.52	0.68	-0.16
Tail	0.63	0.68	-0.05	0.55	0.66	-0.11	0.48	0.67	-0.19

4. SUMMARY, CONCLUSION, AND RECOMMENDATIONS

The SETRIC model is an auspicious tool to be used in assessing the irrigation system performance, particularly for simulating the morphological changes in the canal network. Based on sediment transport simulation and output analyses, it is concluded that the final bed level remains unchanged for concentrations below 130 ppm throughout the selected canal section, as the actual sediment concentration approaches equilibrium levels. Bed level changes are significant for sediment concentration ranging from 300 to 730 ppm. The sediment control results in partial improvements in DPR. It tends to result in equity. The difference in DPR of head, middle, and tail outlets becomes in the range of 0.03 to 0.06, which is negligibly small. The overall maximum DPR is about 0.72, which is much less than 1.0. However, the link between sediment concentration and DPR is weakly established. Statistical evidence, e.g., regression analysis, is required in this regard, showing the correlation between sediment concentration and DPR decline. For this purpose, a huge amount of data is required on DPR and sediment concentration. It is recommended that a full-length research paper be prepared by collecting extensive data on DPR and sediment concentration.

It is worth mentioning that, like other models, the SETRIC Model has some merits and demerits. This manuscript has demonstrated the merits of the model, but its limitations should also be kept in mind. There are several limitations of this model, including its inability to capture all complications of sediment-laden flow completely. Especially in a non-equilibrium state, the three-dimensional motion of sediments is poorly simulated, particularly in terms of bed level changes, compared to three-dimensional and two-dimensional models. 2-D and 3-D models are recommended to be used in the future by collecting extensive required data.

NOTATIONS

Q	**Water discharge**	**RD**	**Reduced Distance**
Q_S	**Sediment Discharge**	**D**	**Diameter**
d	**Flow Depth**	**UCC**	**Upper Chenab canal**
q_{ti}	**Volumetric Sediment Discharge**	**PPM**	**Parts per millions**
SIC	**Simulation of Irrigation**	**g**	**gravitational acceleration**
u^*	**Canal**	**DPR**	**Delivery performance ratio**
v	**Sediment Shear velocity**	**n**	**Exponent in dimensionless mobility parameter**
	Kinematic viscosity of sediment		

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استخدام نموذج SETRIC لدراسة أداء قناة ري تحمل مياهًا محملة بالرواسب

ملخص: تُعد الزراعة ركيزةً أساسيةً لاقتصاد العديد من دول العالم. ويلعب الأداء الأمثل من حيث موثوقية وكفاءة وكفاية نظام الري دورًا هامًا في النهوض الاقتصادي لأي بلد. ويؤثر تراكم الرواسب في القناة بشكل كبير على شكلها، وكذلك على إمدادات المياه اللازمة للزراعة. تتضمن هذه الدراسة تطبيق نموذج عددي لدراسة هذه القضية بالغة الأهمية والتحديات المتعلقة بعملية نقل الرواسب في قناة تشيناب العليا(UCC) ، باكستان. وقد طُبق نموذج SETRIC لدراسة نقل الرواسب في قناة تشيناب العليا. واستُخدمت صيغة مانينغ للتعامل مع خشونة المعادلات الحاكمة. كما اعتُمدت معادلة آكرز ووايت لتقدير حمولة الرواسب. وقد جُمعت البيانات المتعلقة بالتصريف، وتركيز الرواسب، ومنحنى تدرج الرواسب، وهندسة القناة من المكتب الرئيسي لشركة مارالا في سيالكوت. تم فحص حالة القناة، التي جُمعت بياناتها، وتبين أن أداءها ليس مثاليًا. تسحب مخارج الجزء العلوي من القناة كميات أكبر من المياه، بينما لا ترقى نسبة أداء التوصيل (DPR) لمخارج الذيل إلى المستوى المطلوب. طُبّق النموذج لتحديد تركيز الرواسب غير المتراكمة وغير المتآكلة عن طريق الاختبار والتجربة، حتى أصبحت قيم نسبة أداء التوصيل (DPR) لمخارج الجزء العلوي والذيل من القناة متقاربة تقريبًا، مما يُظهر اتساقًا في الإمداد. يمكن تحسين كفاءة القناة بشكل أكبر من خلال السماح بمرور الرواسب غير المتراكمة وغير المتآكلة. ستكون نتائج هذه الدراسة مفيدة للغاية لتشغيل وإدارة القناة.

الكلمات المفتاحية: الرواسب العالقة، التصريف، المقاطع العرضية للقناة، نسبة أداء التوصيل (DPR)، مستوى القاع