Research Article

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A PLAN FOR THE ENHANCEMENT OF BACKWATER FOR IRRIGATION FOR SUSTAINABLE LIVELIHOOD OF RURAL COMMUNITIES AT MAGRAHAT BASIN, SOUTH 24 PARGANAS, WEST BENGAL

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Abstract : Management measure for Irrigation water by tidal back-water influx is an important issue for the sustainable living of rural communities in the areas where the rainfall is insufficient for rabi crop cultivation. Tidal back-water influx is one of the sources of irrigation water in the lower gangetic planes of West Bengal, India. Based on that concept, a plan is provided for the Magrahat basin of South 24 Parganas district in West Bengal for the augmentation of irrigation facilities through excess amount of tidal back-water entry during the post-monsoon period when the salinity of water is considerably low. In the present study, twenty major canals or khals of Magarahat basin are considered. Volume of available tidal water for irrigation of rabi crops was determined from the gauge data of tidal rivers. Here an attempt has been made to delineate not only the enhancement of the economic return of the people of the Magrahat basin but also to create provision for multi-cropping (rabi crops) pattern of agriculture/horticulture facilities during the dry season for sustaining of their livelihood. Also the tidal backwater surface profiles have been suggested for all the major canals of Magrahat basin using standard step method of gradually varied flow.

Keywords : Water availability, tidal back-water influx, gradually varied flow, water requirement of crop, water distribution management.

1. Introduction

The geographical co-ordinates of the Magrahat basin are latitude -22°12′ N and longitude -88°32′ E. The basin area is 612.46 km^2. The tidal back-water conservation measure has been suggested in the Magrahat basin in South 24 Parganas, West Bengal, India, for storing the maximum back-flow influx of the tidal water by controlling the sluice gates at different canals/ khals based on the field survey and monitoring. In this study, twenty major canals/ khals are considered, namely, Dhanpota khal, Nazra khal, Srichanda khal, Diamond Harbour creek khal, Usthi Nainan khal, Sangrampur khal, Keorapukur khal (upper and lower), Magrahat khal, Hotor canal, Dhamua khal, Dashani khal, Kholakhali khal, Jaynagar khal, Hatuganj khal, Suryapur inner channel, Kata khal, Muldia khal, Borar khal and Baharu khal.

Tidal back-water conservation means not only for multi-cropping agriculture and fish production in the Magrahat basin but also serves as a resource-base for many other activities such as the collection of fodder, the making of bricks, baskets, etc., with women offering their willful assistance in these processes. Conservation of tidal back-water is also a part of the socio-economic system in the Magrahat basin. The maintenance of natural resources through a continuous process of use and conservation means not merely the assurance of livelihoods to the people of the adjacent mouza of Magrahat basin, but also the preservation of the ecological balance.

Based upon the information and field studies carried out by the research team in the School of Water Resources Engineering, Jadavpur University, it is conjectured that the erstwhile Diamond Harbour creek khal was an estuarine khal with regular tidal influx. Especially during flash floods, the entire catchments used to be flooded. To eradicate the problem, in early post-independence time, a master plan was prepared by the Irrigation Department of the Government of West Bengal to restrict the entry of tidal ingress by means of a major sluice gate and construction of similar sluices in each estuarine khals, to check the flood problem in the area as also to conserve tidal back-water for use in lean periods.

Only a few studies detail about various types of back-water inflow calculation carried out over past decades. Keifer and Chu [1] made an attempt to determine the backwater function with the help of numerical integration technique. Subramanya [2] investigated and determined the backwater surface profiles of rectangular channels at gradually varied flow conditions. The calculation method for the water level, when the flow is under constant change, was presented by Merkl [3]. An extended form of the Bernoulli formula was applied. The computer program calculation was also discussed. Later Subramanya and Ramamurthy [4] computed backwater open channel flow profiles using direct integration method. Isaacs [5] also described a computer program for composite backwater profiles in trapezoidal channels. There are a few numbers of initiatives taken by the researchers to identify the salt water intrusion problem due to tidal back-water influx. Roy et al. [6] provided a plan for augmenting irrigation water for the development of Kultali block through rain water harvesting structure ponds and suggested crop pattern and crop rotation according to water availability, quality and soil condition. Dhar et al. [7] explored the cartographic nature of the Kultali block of the Piyali River. Later Dhar et al. [8,9] made an attempt to investigate the extent of salt water intrusion phenomenon of the Piyali River. Pre monsoon, monsoon and post monsoon water and soil samples from each village of the Kultali block were also analysed for their contents regarding total dissolved solids, pH and chlorides.

In Magrahat basin, the people are not able to cultivate the rabi crop even though the available water i.e. the tidal influx during non-monsoon period is sufficient for the enhancement of the economic return by cultivation during rabi season. The authority is not able to utilise the tidal influx properly. Thus the main objective is to provide a plan for the augmentation of irrigation facilities through excess amount of tidal back-water influx.

The present study attempts to delineate not only the enhancement of the economic return of the people of the Magrahat basin but also to create provision for multi-cropping (rabi crops) pattern of agriculture/horticulture including pisciculture facilities during the dry season for sustenance of their livelihood.

2. Information/ Data Obtained for Magrahat Basin

- Mouza maps [500 revenue survey (R.S.) mouza sheets] - 226 sheets of Magrahat 1 and 2 blocks, 139 sheets of Kultali block, 135 sheets of Joynagar 1 and 2 blocks.

- Inner channel and outer channel water level data (gauge curves determined from Diamond Harbour creek khal).
- Kultali block map and Index map.
- Hydro-meteorological data of different gauge stations.

3. Measurement of Surface Water

- Rainfall data have been collected from two Diamond Harbour and Sonarpur rain gauge stations. It has been assumed that the rain water is stored in all the canals during every four months (July to October) of the rainy season [10]. Rainwater stored in other months is negligible as compared to the rainy season.
- Lengths of all the canals are determined from the basin map of Magrahat. Bed slope (S_0) of each canal is taken as 1:25000. This area is constructed by an alluvial soil.
- The slope of the earth surface is considered as north to south. So, rain water flows from north to south due to gravity. Watershed areas are divided by roads and rail-lines as these are the cause of water logging.
- Surface runoff of rain water for each watershed area is calculated using a computer (mathematical) model HEC-HMS (Hydrologic Modeling System). Infiltration loss, evaporation loss and percolation losses are calculated. Total discharge is determined with the help of the calculated runoff volume and the channel routing. Routing has been done by applying Kinematic Wave equation (considering trapezoidal cross-section of khal, bed slope, bottom width, energy slope etc). Finally, the discharge is calculated with the help of the HEC-HMS software.
- The entire Magrahat basin is divided into some sub-basins. Watershed areas are drawn and demarcated from the Magrahat basin map.
- Non-silting non-scouring velocity of the tidal water is assumed to be 2 m/s. Critical depths (y_c) {where, the discharge is maximum and the specific energy is minimum} have been calculated using sub-critical flow conditions ($y > y_c$). Hydraulically efficient sections, that is, the best sections where perimeter of the cross sectional area is minimum, are also considered for all khals.

4. Tidal Water Availability

- A field visit is carried out at the Diamond Harbour creek khal for the collection of data (continuously over 4 hours) to produce gauge curve (inner and outer channel) during the tide and ebb effect.
- The total energy slope or friction slope (S_f) is calculated using the Manning's equation $\left(S_f = \frac{n^2V^2}{R^{4/3}}\right)$, where the Manning's coefficient (n) is equal to 0.00275 [11].
- Backwater surface profiles or gradually varied flow profiles have been determined by using the Standard Step Method [12] for natural channels. The following finite difference equation is used to determine the backwater curve due to tidal inflow flux :

$$\Delta x = \Delta y \left(\frac{1 - F_r^2}{S_0 - S_f} \right)_{mean} \qquad (1)$$

where F_r is the Froude number, Δx and Δy denote the change of distance along the horizontal and vertical direction. Here, 'mean' refers to the mean value for the interval Δx. This form of equation is used to determine, directly, the distance between the given differences of depth for any trapezoidal channel. Here the flow region is found to be subcritical ($F_r << 1$).

- The critical depth (y_c) is determined using the following equation :

$$y_c = \left(\frac{Q^2/B^2}{g}\right)^{1/3} \qquad (2)$$

where, Q is the discharge, B is the bottom width of the khal.

5. Water Requirement for Crops at Magrahat Basin

It is assumed that the, gross command area (GCA) is equal to the watershed area. 10% unculturable area is considered. Therefore, the culturable command area (CCA) becomes 90% of GCA. The intensity of irrigation is assumed 95% of CCA. Base period is assumed to be 120 days. Irrigation areas for kharif and rabi crops are also assumed to be 20% and 60% of the CCA, respectively.

Horticultural crops, suggested for Magrahat basin are brinjal, bhindi, leafy vegetables, pumpkin, bitter gourd, bottle gourd, ridge gourd, potato, cabbage, tomato, bean, chili and watermelon.

6. Determination of Annual Tidal Water Availability

Rabi crops are cultivated from October to March. The feeding of tidal water for rabi crops is done during the four months (December to March) from the Diamond Harbour creek khal. It is done because, before and after this period, the tidal water becomes very salty. And also, there is no need of tidal water during the four months of the rainy season and the period (November) of the extraction of the water required at the last stage of aman crop. So, the tidal water is needed for the four months (December to March) only.

Feeding of the tidal water is done twice daily. So, it is 24 times per month. So, during the 4 months (December to March), the tidal water feeding is done 24 × 4 times, i.e., 96 times.

The average water depth in the Diamond Harbour creek khal increases by 1.2 meter due to the feeding of one tide (data obtained with the help of the gauge curve). On an average, the tidal water is fed for 4 hours and 30 minutes from this khal in each feeding (according to the gauge curve determined). In this khal, the tidal water velocity increases by 2 m/s as compared to the non-tidal velocity. At that time, the average upper width of that khal is 33.6 m. Before, the tidal water feeding the average upper width of that khal was 30 m. At present the length of the Diamond Harbour creek khal is 15.25 km. Therefore, the amount of water in this khal fed by a single tide is 1.6135 MCM. So, the total amount of water in this khal fed by 96 tides is 154.89 MCM per year.

At present :

Name of the crop	Percentage of irrigation
Boro paddy	75%
Vegetables (brinjal, bhindi, sugar beet, chili, cabbage, tomato, pumpkin, bitter gourd, bean, water melon, leafy vegetables)	10%
Mustard	5%
Sunflower, potato etc.	10%

Designed :

Name of the crop	Percentage of irrigation
Boro paddy	25%
Vegetables (brinjal, bhindi, potato, chili, cabbage, tomato, pumpkin, bitter gourd, bean, water melon, leafy vegetables)	25%
Mustard	25%
Sugar beet	20%
Sunflower etc.	5%

7. Name and Percentage of Cultivated Crops in Magrahat Basin

The charts shown above are obtained with the partial help of the Canal Division.

8. Results and Discussion

Total annual tidal inflow in 20 major canals is calculated to be 330.30 MCM. Based on the existing crop pattern, water requirement for crops, in this basin, is estimated to be 335.22 MCM per year. So, at present there is a 4% shortage of water in this basin. Now, the designed water requirement for crops in this basin is 295 MCM per year. So, if the designed crop pattern is maintained there will be 12.18% of excess water. This 12.18% of excess water can be distributed to the Piyali basin (Kultali block), the Jaynagar basin and the SAMD (Sonarpur-Arapanch-Matla Division) Part-1 (Champahati, Begampur, etc.) for the cultivation of rabi crops. Further storage of the excess water is possible if one re-excavates old creeks, canals and ponds. After the re-excavation, approximately 30% of excess water can be stored and distributed to other basins. Now, 40% area of the SAMD Part-2 basin may be cultivated (rabi crops) using this excess amount of water. In this regard, there is a need of rain water harvesting in the SAMD Part 1 and 2.

Fig.1 indicates the gauge curve (inner and outer channel) during the tide and ebb effect at the Diamond Harbour creek khal where the zero (0) line indicates 2.3165 meter depth of the water level.

The normal depth line, the critical depth line and the backwater surface profile curves for Diamond Harbour Creek khal, Dhanpota khal, Nazra khal, Sangrampur khal, Srichanda khal and Usthi Nainan khal are depicted in Fig.2(a-f) where the length of the backflow for these khals are 10.2, 3.4, 5.4, 5.8, 4.0 and 10.6 km, respectively. Based on the calculated backflow length there must be a regulator at the inlet of the Dhanpota khal. Then the excess water can be distributed to the Jaynagar khal and the Kata khal. In case of the Nazra khal, there must be two regulators at the inlet and the outlet of this khal. Then the excess water can be distributed to the Hatuganj khal. There must be a regulator at the inlet of the Sangrampur khal also for distribution of the excess water to the Jaynagar khal and the Kata khal. The Srichanda khal must be controlled by a regulator at the inlet to distribute the extra amount of tidal energy to the Usthi-Nainan khal. Lastly, for the Usthi Nainan khal the extra amount of water can be distributed towards the Keorapukur khal and the Magrahat khal. The Suryapur inner channel can be fed with the extra amount of water from the Magrahat khal by which the water can be distributed to the Kultali basin (mainly the Piyali river).

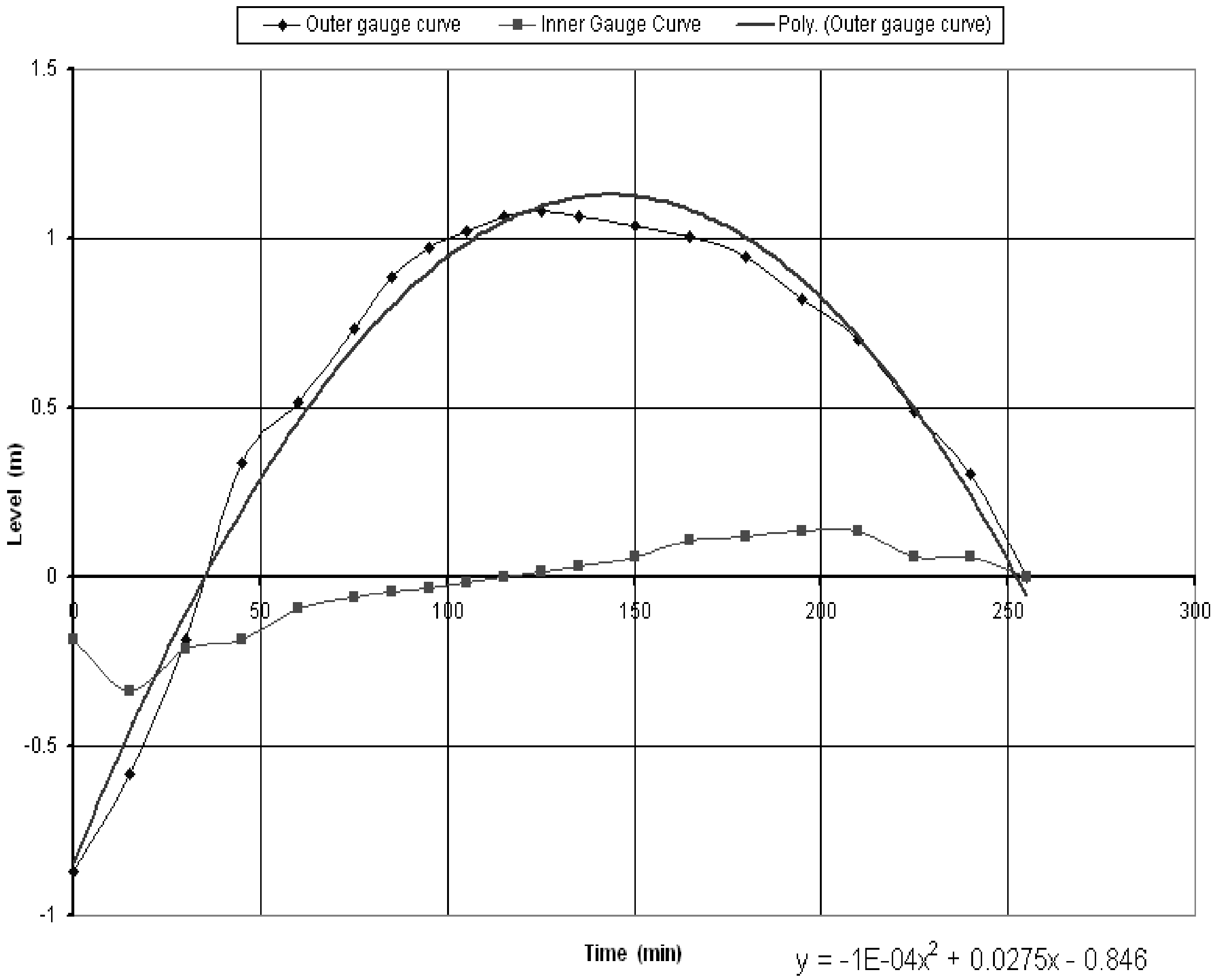

Fig.1 Gauge curve (inner and outer channel) during tide and ebb effect at Diamond Harbour creek khal

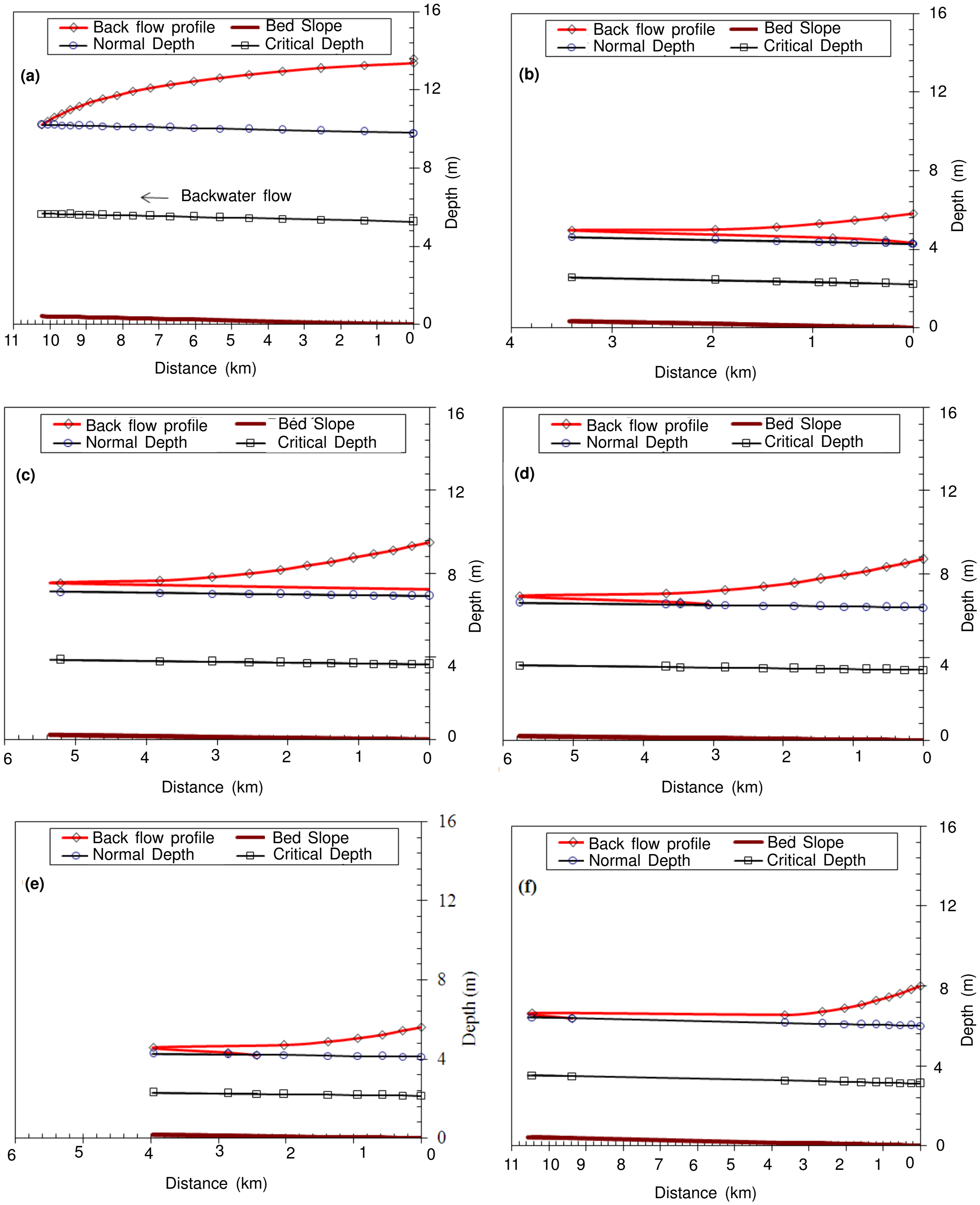

Fig.2 Backwater surface profile curves for (a) Diamond Harbour Creek khal, (b) Dhanpota khal, (c) Nazra khal, (d) Sangrampur khal, (e) Srichanda khal and (f) Usthi Nainan khal

Table 1 Calculation for major khals in Magrahat basin

Sl. no.	Name of the canals	GCA (km^2)	CCA (km^2)	Tidal inflow (MCM)	Present water requirements for crops (MCM)	Designed water requirements for crops (MCM)
1	Diamond Harbour creek khal	55.48	35.58	77.22	31.49	27.75
2	Kholakhali khal	11.66	7.48	29.82	6.62	5.83
3	Dashani khal	15.28	9.80	24.37	8.67	7.64
4	Srichanda khal	51.46	33.00	22.94	29.21	25.74
5	Usthi Nainan khal	32.97	21.14	36.00	18.71	16.49
6	Nazra khal	5.23	3.35	33.90	2.97	2.61
7	Sangrampur khal	39.40	25.27	14.99	22.36	19.71
8	Hatuganj khal	9.65	6.19	12.60	5.48	4.63
9	Keorapukur khal (lower)	75.59	48.71	14.71	43.11	37.99
10	Keorapukur khal (upper)	87.65	42.01	5.04	37.18	32.77
11	Hotor khal	27.34	17.53	5.06	15.52	13.67
12	Dhamua khal	19.30	12.38	4.10	10.95	9.65
13	Magrahat khal	2.54	1.63	11.21	1.44	1.27
14	Suryapur inner channel	53.47	34.29	11.21	30.35	26.75
15	Kata khal	49.45	31.71	6.52	28.07	24.74
16	Jaynagar khal	29.85	19.14	7.22	16.94	14.93
17	Muldia khal	8.85	5.67	9.23	5.02	4.42
18	Dhanpota khal	24.93	15.98	4.76	14.15	12.47
19	Borar khal	5.93	3.81	0.26	3.37	2.84
20	Baharu khal	6.43	4.13	2.14	3.65	3.08
	Total	**612.46**	**378.80**	**333.30**	**335.22**	**294.99**

Table 2 Other basins related to Magrahat basin

Sl. no.	Name of the canals	GCA (km^2)	CCA (km^2)	Tidal inflow (MCM)	Present water requirements for crops (MCM)	Designed water requirements for crops (MCM)
1	Falta	139.86	97.90	54.76	86.64	53.85
2	Kholakhali	38.85	27.19	42.59	24.07	15.91
3	Kantakhali	93.24	55.94	73.01	49.51	32.73
4	Raipur	82.88	41.44	36.51	36.67	24.24
5	Charial	129.50	64.75	48.68	57.30	37.88
6	Manikhali	56.98	11.40	42.59	10.09	8.47
	Total	**541.31**	**298.62**	**298.14**	**264.28**	**173.08**

Table 3 Active sluices in other basin considered for calculation

Sl. no.	Name of the other basin	Name of active sluices
1	Falta	Falta sluice, Nainan sluice, Nila sluice, Nurpur Hathkhola sluice, Nurpur sluice
2	Kholakhali	Kholakhali sluice, Balarampur sluice, Bhawanpur sluice, Roychak sluice, Kalishankarpur sluice
3	Kantakhali	Kantakhali sluice, Kharipota sluice, Rajarampur sluice, Ammedpur sluice, Paddapukur sluice, Burul sluice (old), Burul sluice (new), Naldari sluice, Bahirkunja sluice
4	Raipur	Raipur sluice, Alumpur sluice, Mayapur sluice, Achipur sluice
5	Charial	Manikhali sluice (old), Manikhali sluice (new), Hayatpur sluice, Nungi sluice, Chakchandul sluice
6	Manikhali	Charial diversion (Pujali sluice), Charial main sluice

8. Conclusion

The present work has been carried out for the Magrahat basin. Total GCA and CCA of the Magrahat basin are 612.46 km^2 and 378.80 km^2, respectively. Twenty major canals are considered in the calculation of water availability in the Magrahat basin. Total annual tidal inflow in twenty major canals is 330.30 MCM. Present water requirement for crops in this basin is 335.22 MCM per year. So, at present there is a 4% shortage of water in this basin. Designed water requirements for crops in this basin will be 294.99 MCM per year. So, the designed crop pattern will ensure 12.18% of excess water. This 12.18% of excess water can be distributed to the Piyali basin (Kultali), the Jaynagar basin and the SAMD Part-1 (Champahati, Begampur etc.) for the cultivation of rabi crops. Further storage of excess water is possible if one re-excavates old creeks, canals and ponds. After the re-excavation, approximately 30% of excess water can be stored and distributed to other basins. Now, 40% area of the SAMD Part-2 basin may be cultivated (rabi crops) using this excess amount of water. In this regard, there is a need of rain water harvesting in the SAMD Part 1 and 2. This research study has been done with the help of technical calculations and theoretical information. Some information has been collected from the Magrahat Canal Division. However, smaller reservoirs and canals (excluding the above mentioned 20 canals) are not considered here. So there may be a small difference in the calculated results related to the water availability in the Magrahat basin.

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