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TATA CONSULTING ENGINEERS LIMITED

Salinity Contingency Planning – East Medinipur

Screening of options

Asian Development Bank

Technical Note

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Technical Note

November 2019

The expert in **WATER ENVIRONMENTS**

Salinity Contingency Planning – East Medinipur

Screening of Options

Prepared for	Asian Development Bank
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The water intake site at Rupnarayan River on Nov. 12, 2019

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Executive Summary

Following a review early July 2019 by the TA Smart Water Management Consultancy team of a salinity modelling study by IIEST of the East Medinipur intake area, it was found that measured salinity levels exceeded the permissible limit (500 ppm) as defined by the Indian Drinking Water Standard IS:10500 during the Summer season. Subsequently, ADB requested the TA to carry out a rapid study for identifying and analysing contingency options to solve this salinity issue.

This note includes 1) background description, 2) explanation of the salinity dynamics, 3) measurements of salinity and analyses using a coarse pilot model, 4) review of the climate change action plan of the state, 5) description of solutions, and 6) recommendations for action.

Background

The tender documents for bulk water works including building of a new water intake at Mirpur mention that salinity is being investigated in a modelling study, and that the Contractor shall therefore consider the probable impacts in their design and quoting. However, the scale of the salinity issue is unknown, and therefore how much is inside the existing scope of the Contractor.

Salinity dynamics explained

Three main freshwater surface sources (Hooghly River, Damodar/Mundeswari River, minor adjacent river basins) balance the tidal intrusion of saline water. The lesser freshwater flow, the higher salinity. The Hooghly river is the biggest contributor to freshwater. Damodar River is the second biggest. Operation of Farakka barrage and structures in DVC’s command area is vitally important for the salinity at the intake site. During low tide, saline water is pushed seawards and results in lower salinity upstream. The nearby Geonkhali and Panskura WTP have been studied.

Salinity measurements from 2010 to 2019 and pilot modelling

Four independent sources of salinity measurements from different agencies are consistent and confirms that the salinity at the site exceeds the permissible 500 ppm and may even go close to 2000 ppm. Analyses supported by salinity modelling using a pilot (still not fully calibrated) model show three type of situations during a typical year: For 2-3 months per year, the threshold is exceeded throughout the tidal cycle, for 3-4 months per year, this happens partly (during high tide only), and for the remaining 5-7 months, the threshold is never exceeded. In a dry year (like in 2016) the time of too high salinity is much longer.

Mitigation solutions

Solutions have been identified with due consideration of the State Action Plan on Climate Change: 1) Smart water monitoring for accurate prediction of threshold exceedance to identify suitable pumping windows for fresh water, 2) additional buffer storage with day-, week- or month-wise storage capacity recognising that the storage can be either on the surface and or in aquifers, 3) transmission lines from remote sources, 4) provision of groundwater as a backup, 5) barrage and sluice gates to prevent or limit salinity intrusion, 6) desalination when the salinity level is above 500 ppm, 7) additional releases either from Hooghly or from Damodar rivers, 8) shifting of water intake further upstream, 9) acceptance of lower service level compliance with time-varying drinking water quality and online (Smart Water) consumer notifications.

Recommendations

Options (1) and (9) are already included as ‘Smart Water’ in this project. Option (2) and (4) are recommended in a first phase once experience is gained after starting the scheme. In a second phase, option (2) with larger nature-based reservoirs along Rupnarayan River can be implemented for long-term sustainability. Option (5) and (6) will only be relevant in the very far future, and only if is combined with a wider planning of e.g. new bridge connection (5) or radical new improved and robust technology. (3), (7) and (8) have been considered but assessed to be non-viable. This phased solution allows the current bid process and project implementation to go on as planned.

1 Background

WBDWSIP has launched an ambitious sub-project in East Medinipur with piped water supply to every household in rural areas extracting surface water from the Rupnararyan River. One key motivation is too high salinity levels in ground water from tube wells. Due to the proximity to the Bay of Bengal, the surface water salinity may also exceed critical levels during the Summer season. This may be further exacerbated in the future by climatic changes with more severe cyclones causing more seawater intrusion or less rainfall outside the monsoon season resulting in less freshwater in the rivers.

In the work tender for EM-01, see Reference /1/, it is therefore specifically mentioned under Section 1.1 Scope of Work (page 3) "*The Employer is currently carrying out a Salinity Modelling for the entire area under the jurisdiction of this work package under consideration. The Contractor shall consider the probable impacts on the equipment design and during implementation for all civil, electro-mechanical and instrumentation items in their scope of works and include the same while quoting for the package. The Contractor shall be responsible to incorporate climate resilience measures as recommended in the CRVA report attached as Annexure 5*". It is further specified (Ref. /1/, Section 1.1.2.2 Chemical Quality, page 4): "*Other chemical quality parameters shall not exceed the acceptable limits specified in the MANUAL OF WATER SUPPLY AND TREATMENT (Latest Edition) published by the Ministry of Urban Development, New Delhi (India) & IS: 10500 (latest edition) and the method of sampling shall be as provided therein*". The Indian Standard for Drinking Water Quality is found in Ref. /15/. In the following, it is assumed that salinity and total dissolved solids TDS is the same although salinity is in principle just a subset of TDS. However, for larger concentrations (above 500 mg/l) it is practically the same. The unit can be in ppm parts per million or in mg/l milligram per litre, which is the same. The Indian standard species: "*It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected*". The acceptable limit for TDS is 500 mg/l. The permissible limit for TDS is 2000 mg/l.

Survey results from the ongoing salinity modelling study, Reference /2/, confirmed that salinity levels of raw water at the intake site would exceed threshold levels of salinity for potable water.

The TA Consultant has subsequently been requested to contribute with identification of possible contingency solutions for mitigating such salinity issues at the water intake. This note presents an appreciation of the identified challenge and how it has been solved in adjacent water schemes, the underlying data documentation as well as sketches of possible solutions.

2 Salinity Issue Appreciation

2.1 Physical conditions in the estuarine area

The project site is in the Ganges delta, see Figure 2-1. The three main freshwater surface sources are Hooghly (connected to Ganges), Damodar and regional adjacent river basins Dharkeswar and Shilabati.

The flow in Hooghly river is controlled by the Farakka barrage more than 300 km upstream. The barrage diverts a minimum flow of around 1000 m³/s from the Ganga into Hooghly River in the dry season of which some is extracted before reaching the Hooghly/Rupnarayan estuary. The flow in Damodar is controlled by upstream barrages (e.g. at Duragpur) and reservoirs (e.g. at Maithon) under DVC and can go down to 30-50 m³/s in the dry season. The rain fed Dharkeswar and Shilabati river basins have even less flow in the dry season. The mean tidal range in Hooghly estuary is in the order of 3-4 m.

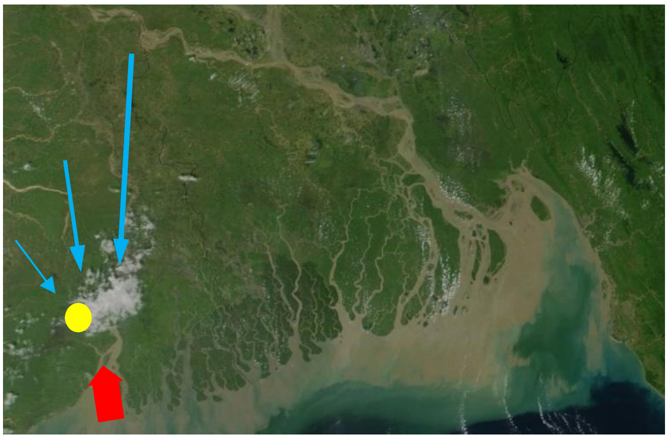

Figure 2-1 The Ganges delta. Water intake: Yellow dot. Freshwater: blue arrows. Saline: red arrow.

During flood (rising tide), saline water propagates up through the river systems, and during ebb (falling tide) the saline water recedes and the freshwater from the upstream rivers dominates. The balance between freshwater and saline water therefore exhibits a diurnal variation with dominating freshwater during low tide and dominating saline (or brackish) water during high tide. The closer to the sea, the more the balance is pushed towards more saline water. The balance is further changed as a function of the amount of freshwater discharge i.e. the season of the year and/or upstream release of water, tidal range (neap and spring tide in fortnightly cycles), storm surges.

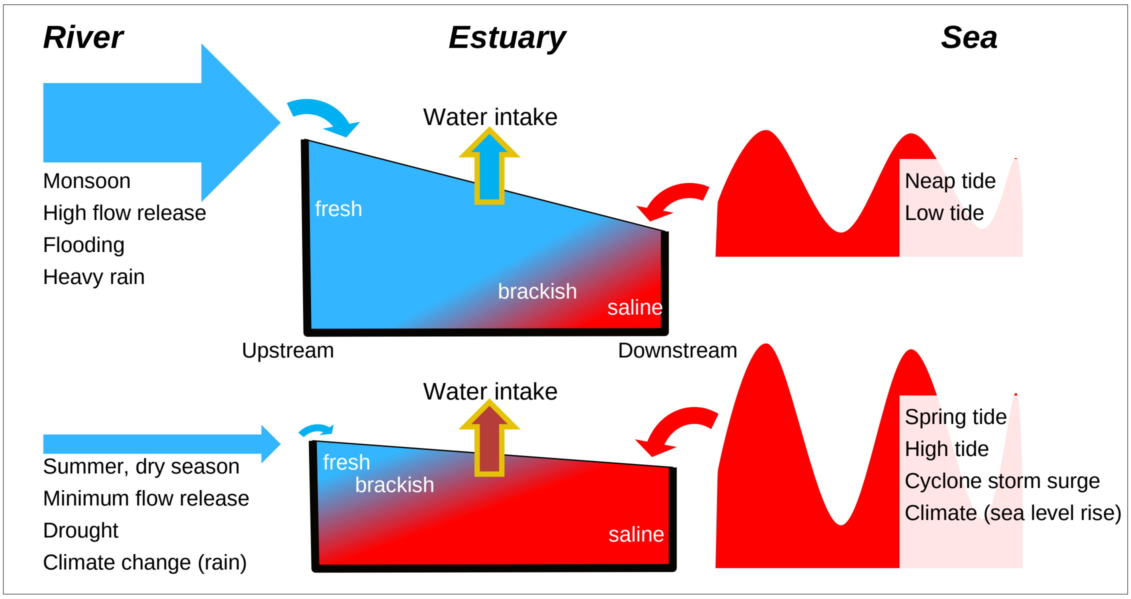

Figure 2-2 Schematic illustration of the “battle” between fresh and saline water in estuaries. Two cases.

Two existing water treatment plants in the vicinity of the proposed water intake at Mirpur, one on either side of this new intake, deal with these salinity issues in different ways. The conditions at Geonkhali water intake (downstream of Mirpur) and Panskura water intake (upstream of Mirpur) are therefore described in the following.

2.2 Geonkhali Water Treatment Plant

A brief summary of salient features at the Geonkhali treatment plant, which is located 12 km further downstream of the new intake (and therefore also having issue with high salinity in the dry season) is provided below. Data is based on Reference /3/.

Haldia is an important industrial town with the presence of several water demanding industries such as Haldia Petrochemicals Limited and Mitsubishi (MCCPTA). The residential population in Haldia is approximately 200,000. Haldia Development Authority (HDA), the nodal agency and Statutory Authority in charge of development of urban and industrial infrastructure including water supply, supplies treated water to industrial, commercial, domestic and municipal consumers, see the table below. Industrial water use is by far the biggest category, and where there may be less strict demands as compared to potable water for the other categories.

Table 1 Water demand MLD at Geonkhali now (before) and future project (proj).

Category	Now (before 2016)	2016 (projected)	2017 (projected)	2018 (projected)	2019 (projected)	2020 (projected)
Industrial	117.77	129.12	151.82	204.03	204.03	204.03
Commercial	0.59	0.59	0.59	0.59	0.59	0.59
Domestic	7.95	7.95	8.31	8.31	8.31	8.31
Municipal	16.53	18.16	18.16	18.61	18.61	18.61
Total	**142.83**	**155.81**	**178.88**	**231.54**	**231.54**	**231.54**

A water treatment facility of 113 MLD (25 MGD) capacity was set up at Geonkhali in 1992. In addition, there are fourteen deep tube wells (total capacity: 9 MLD i.e. 2 MGD) within the Haldia Planning area to supplement potable water supply to the Booster Pumping station at Chaitanyapur and to compensate for any resultant salinity. Construction and commissioning of an additional 113 MLD (25 MGD) WTP has been operational since December 2014. It uses the existing raw water inlet channels and pre-settling tank (900 ML capacity) as a common facility. HDA is now having at its disposal, combined water treatment capacity of 236 MLD (52 MGD) with 227 MLD (50 MGD) from water plants and 9 MLD (2 MGD) from tube wells.

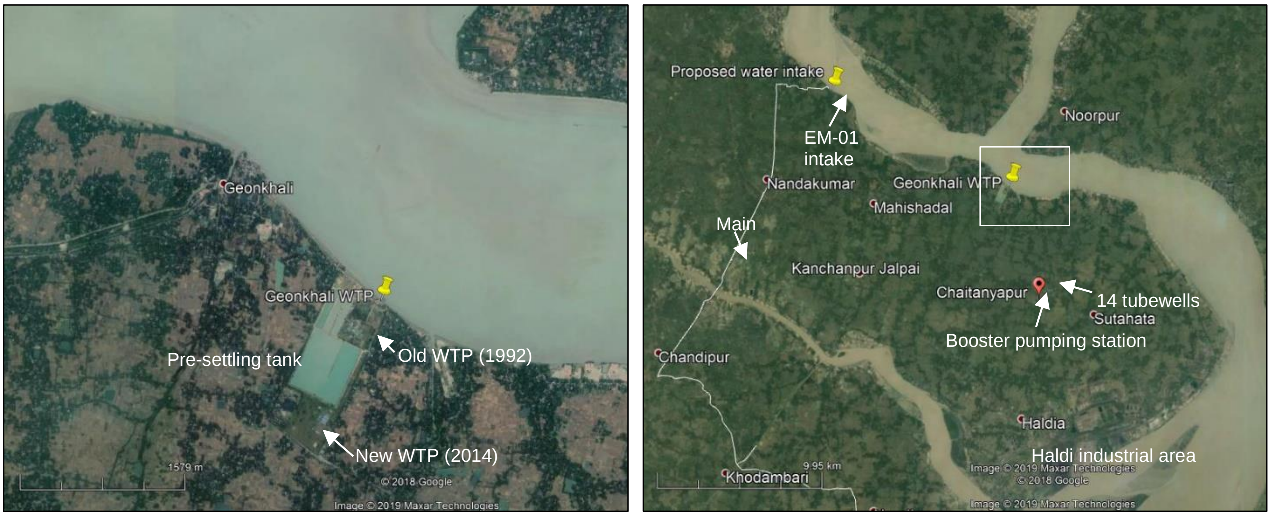

Figure 2-3 Geonkhali WTP (left) and larger view of East Medinipur (right) showing also part of EM01.

The water treatment plants get raw water from the Hooghli river through an intake jetty, located close to the confluence of the rivers Rupnarayan and Hooghli. Two challenges are high turbidity (suspended sediment due to high currents) and high salinity. High turbidity may also be a problem at the proposed new intake but this has not been investigated further.

Turbidity reaches around 1600 NTU (533 mg/l) during monsoon. High turbidity is managed using a 900 ML (900 million litre, 900,000 m^3, 600m×500m×3m), capacity of pre-settling tank, which receives raw water through three inlet channels. The pre-settling tank also serves another purpose being a buffer tank (900 ML divided by 113 MLD is 8 days of buffer) see below.

Salinity level reaches more than 2000 ppm during the dry season of the year when there is no freshet in Hooghly and during high tides. High salinity level is managed by mixing water drawn from the estuary with ground water drawn from 14 tube wells at Chaitanyapur boosting station (9 km from Geonkhali) before distribution. During low tide, water quality is generally of acceptable level especially outside the Summer season, see the table below, and salinity issue remains under control. Thus, by controlling intake flow of water over the tidal cycle, a proper mix secures sufficiently low salinity of distributed water.

Table 2 The salinity levels of raw water at the existing Geonkhali intake. Threshold is 500 ppm.

Season	Period	Duration (months in a year)	Semi-diurnal, low tide hours		Expected salinity range during low tides (ppm)	Remarks
			1st cycle (hours)	2nd cycle (hours)		
Monsoon	3rd week of June to October	4.50	8	8	20-100	Fresh water
Post-monsoon	Nov to 3rd week of Feb	3.75	5.5	5.5	60-300	Fresh water
Summer (dry)	Last week of Feb to 2nd week of June	3.75	3.5	3.5	450-900	Saline water

The chloride and salinity levels in the Summer for different years are shown below (using the formula: Salinity (ppm) = 1.8066 Cl^- (ppm), note that the conversion is not accurate for low-saline brackish water due to varying concentrations of other types of ions than chloride). Considerable variation from one year to another is noted, which is due to natural fluctuations in dry-season river flow. Long-term climatic changes such as sea level rise or rainfall-runoff changes will also have impact on these salinity levels.

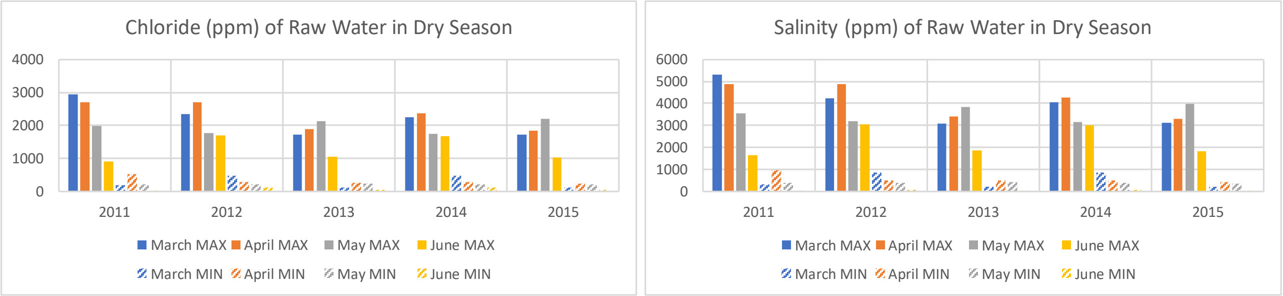

Figure 2-4 Observed chloride and salinity concentration 2011-2015 (MIN=minimum at low tide and MAX=maximum at high tide) of raw water intake at Geonkhali WTP (Ref. /3/).

The salinity issue is being addressed by HDA by strict monitoring of salinity levels during low tides, prudent operation of pumps and mixing treated water with ground water from the existing bore wells near Chaitanyapur Pumping Stations.

2.3 Panskura Water Treatment Plant at Kolaghat

The new water intake for Panskura water treatment plant (Panskura-II) was commissioned in 2018. There is no particular provision for lowering the salinity levels in raw or treated water (oral communication).

3 Analysis of data from water intake site

3.1 Salinity data from CPCB

Monthly spot samples (i.e. at a given date and time) of total dissolved solids by West Bengal Pollution Control Board, see Reference /4/, from 2011 and onwards are shown below. Data are shown from three stations: At Kolaghat 25 kilometres upstream of the intake, at Geonkhali 12 kilometres downstream, and at Diamond Harbour 25 kilometres downstream. Note that the variation over one diurnal tidal cycle or a spring-neap biweekly tidal cycle is not detectable. This diurnal variation can be seen in new surveys from 2019, see Figure 3-5. Nevertheless, data in Figure 3-1 shows that salinity exceeds the threshold of 500 mg/l every year.

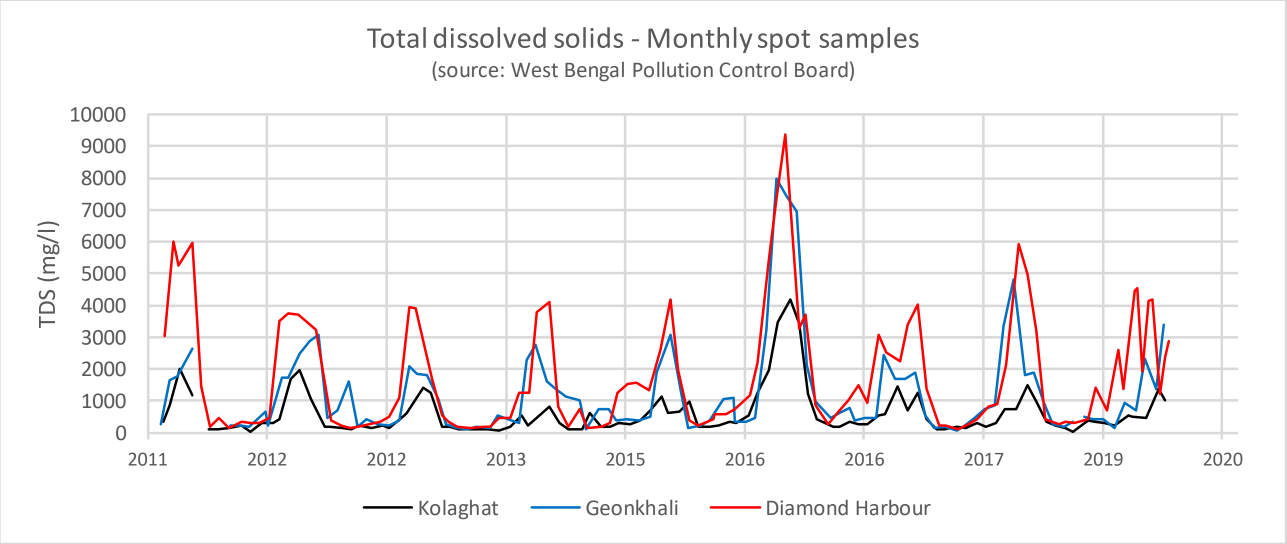

Figure 3-1 Observed total dissolved solids (salinity) concentration 2011-2019. (Ref. /4/).

From Year reports by Central Pollution Control Board, Reference /5/, minimum and maximum values of conductivity can be extracted and converted into approximate TDS values (using a conversion factor of 0.64). Values from 2012, 2013, 2014 and 2016 exist, see below.

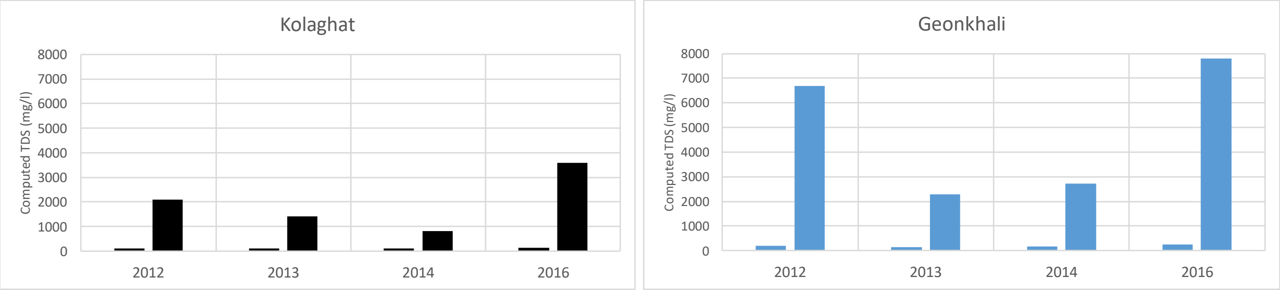

Figure 3-2 Minimum and maximum levels of total dissolved solids (salinity) calculated from conductivity measurements at Kolaghat and Geonkhali. Source: Reference /5/.

3.2 Salinity data from PHED

The concentration of total dissolved solids as a measure of salinity is depicted below. It is monitored by Public Health and Engineering Department, PHED, at the upstream Panskura and downstream Geonkhali Water Treatment Plant.

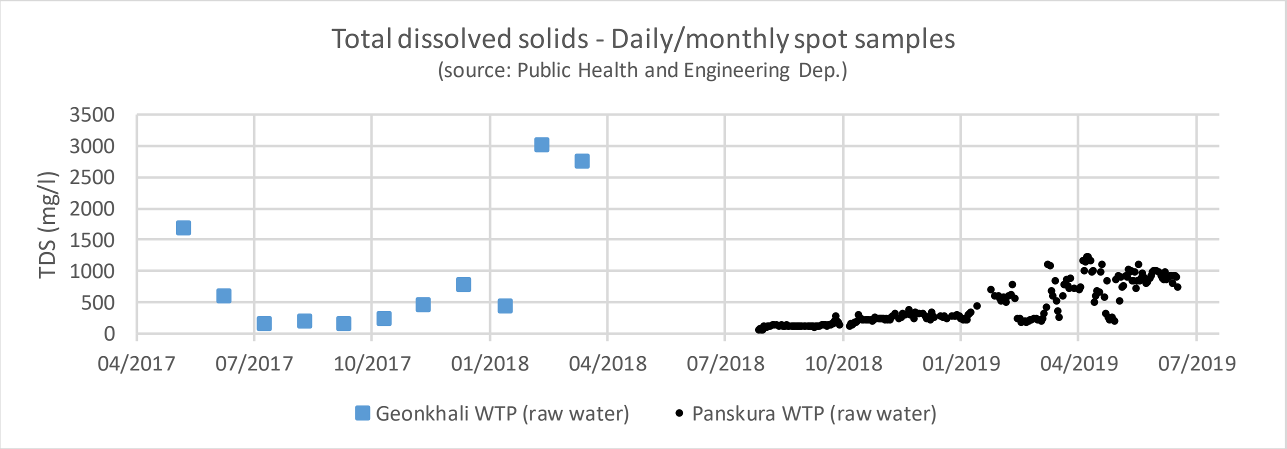

Figure 3-3 Observed total dissolved solids (salinity) at Geonkhali WTP and Panskura WTP. Data from PHED covering April 2017 to July 2019. Source: Reference /6/.

The comparison of data from the two sources, PHED and CPCB, respectively, is shown below. Considering daily tidal fluctuations, there is good correspondence between the two data sets.

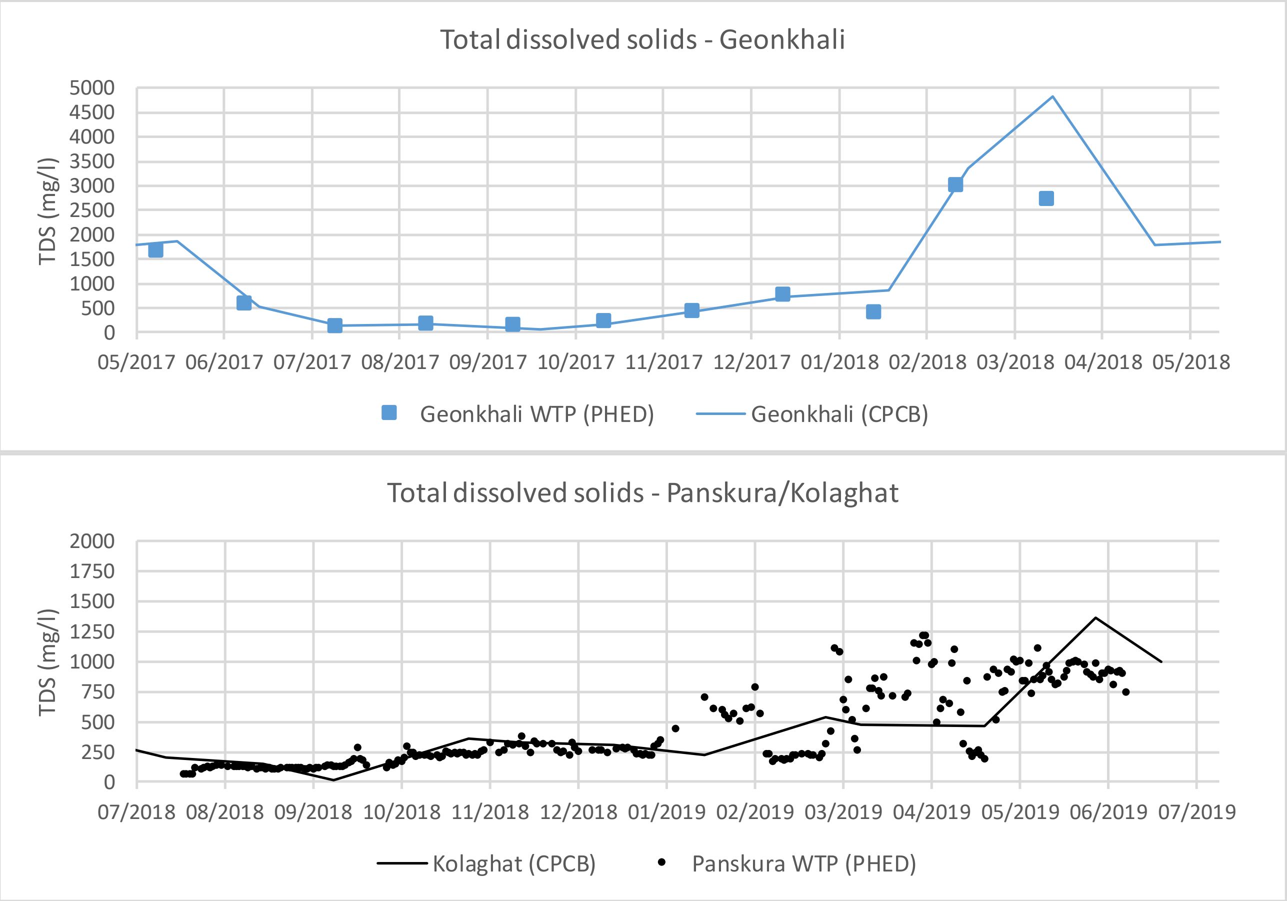

Figure 3-4 Comparison of observed total dissolved solids from two sources, CPCB and PHED. Source: Reference /4/ and /6/.

A field survey was carried out at the water intake site in May 2019. The results of the salinity and total dissolved measurements are shown below together with the water level. As expected, the salinity is maximum at high tide and lowest at low tide.

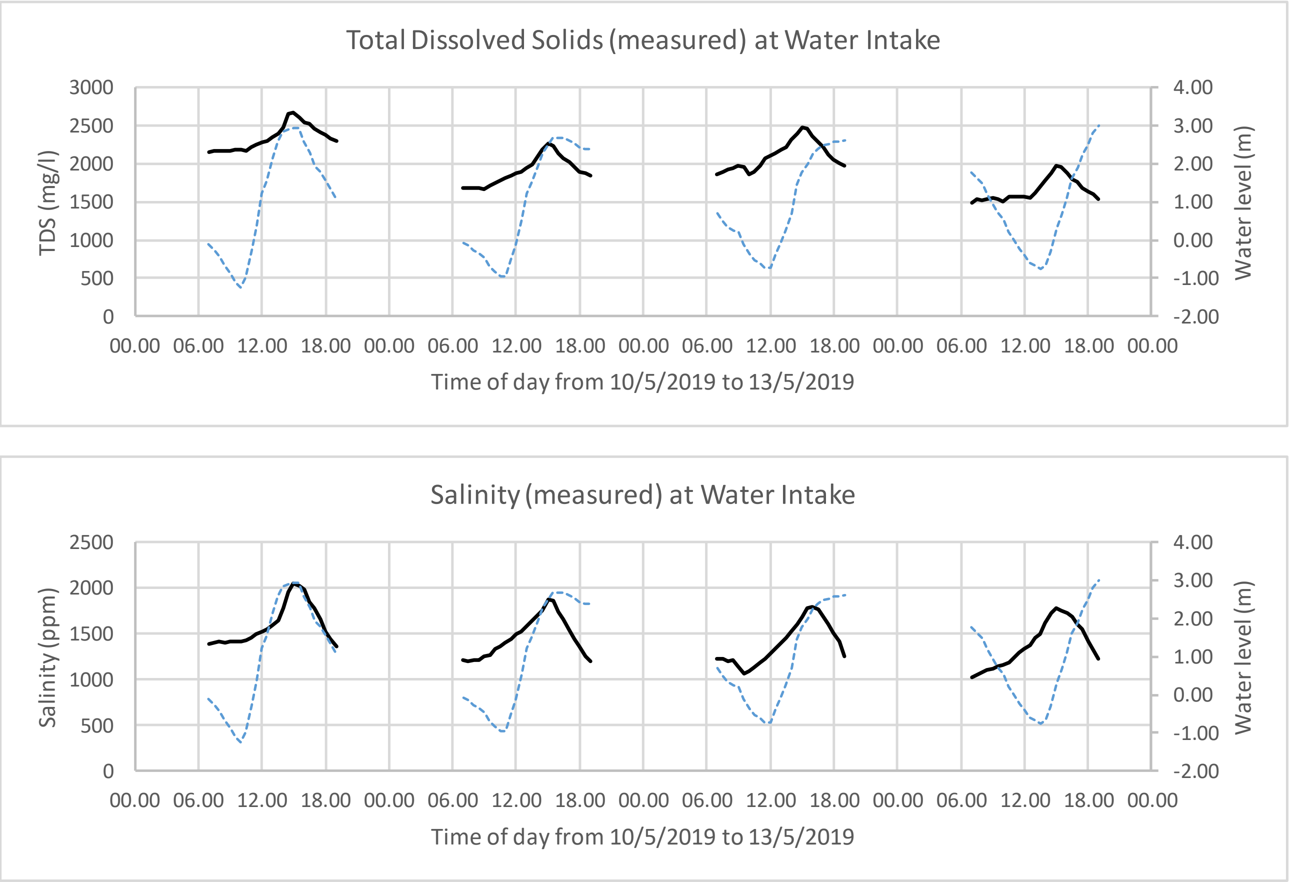

Figure 3-5 Recent survey of TDS and salinity at the intake site. The water level (relative to a local datum) is shown as a blue dotted line. Source: Reference /7/.

All salinity data shows consistently, that the proposed intake site will have TDS and salinity levels exceeding a threshold of 500 mg/l and even 2000 mg/l regularly and particularly 4-5 months (March to June-July) around the Summer season.

3.3 Regional salinity modelling

A pilot model based on one-dimensional flow and transport equations (Ref. /8/) has been established of the entire estuary system. A schematic overview is provided in Figure 3-6 and the actual model layout is shown in Figure 3-7 below. As data is still being collected, synthetic (but as close to realistic as possible) time series of flow and tidal water levels have been applied. Until real data from CWC, IWD, KoPT etc. have been released, collected and checked, final calibration cannot be completed. The model remains a pilot model until then.

Although not fully calibrated, the hydraulic model which simulates 3 years provides an excellent insight into the dynamics of channel discharges and water levels over diurnal tidal cycles, fortnightly neap-spring cycles, annual season flow cycles, cyclone storm surge events and even variations in flow from one year to another can be simulated to see the impact on salinity. For this pilot model, synthetic timeseries of tide was constructed based on information about tidal range and neap-spring differences. Storm surges have not been included in this timeseries.

For salinity, an advection-dispersion model algorithm is added on top of the hydrodynamic model. At the downstream boundary (the Bay of Bengal), the salinity is assumed to be 35,000 ppm as a rough estimate. This is the average salinity in the World's oceans. For the Bay, it might be too high because of the supply of freshwater to the bay area and subsequent mixing. Once the model gets properly calibrated, a seasonal variation in salinity in the Bay area must be included. At the upstream river boundaries, the salinity is assumed to be 0 ppm for the sake of simplicity of the pilot model: The extent of the model area has been chosen to ensure salinity intrusion is not extending to the upstream boundaries. In a fully calibrated model this must be verified.

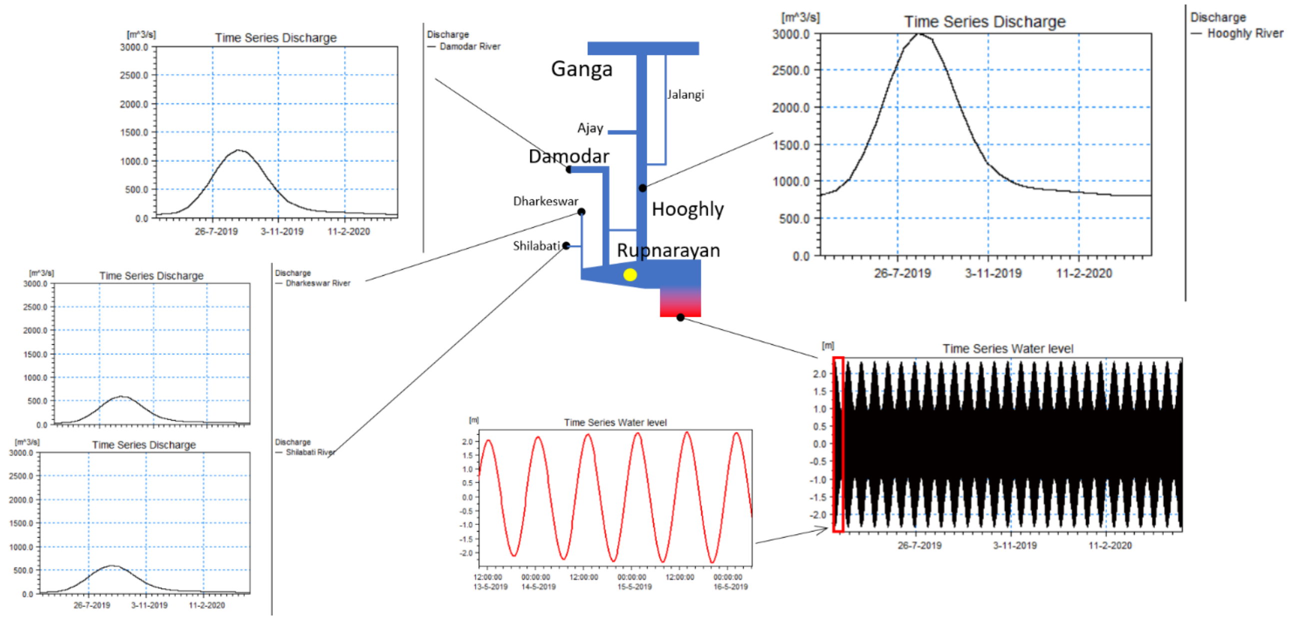

Figure 3-6 Schematic overview of the one-dimensional regional flow and transport model.

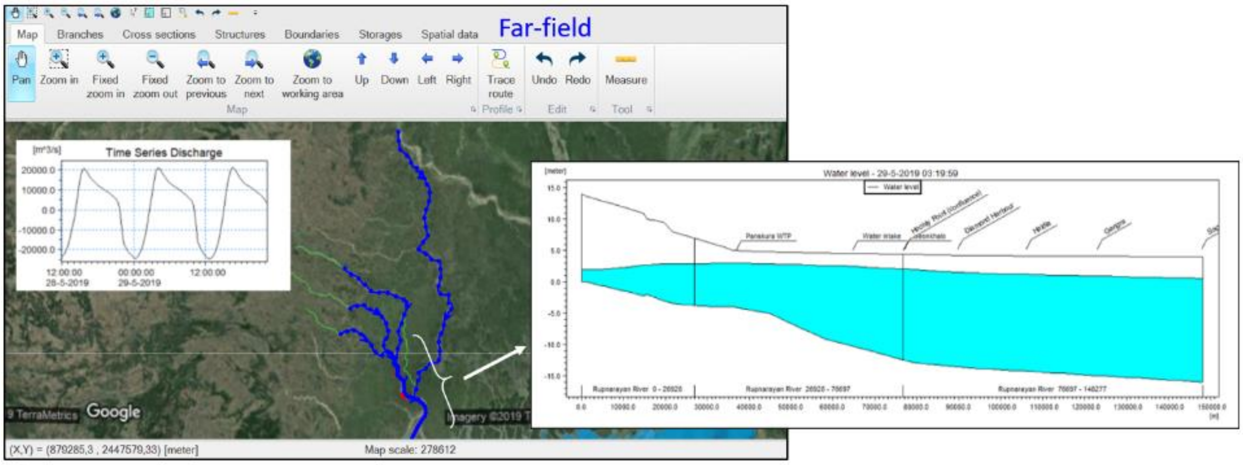

Figure 3-7 The one-dimensional regional flow and transport model. The channel network is shown as blue lines. Example of simulated tidal discharge is shown in upper right corner. The longitudinal profile of simulated water level from the Sea and up into Rupnarayan is shown to the right.

The salinity advection-dispersion model is yet not fully calibrated[1]. Especially, the dispersion is essential to calibrate more accurately by comparing simulated and observed salinities. However, simulated values of salinity at the intake site at Mirpur of the first year of simulation, see Figure 3-8 lower figure, are quite comparable with the measured data, see Figure 3-5. The upper figure in Figure 3-8 , show that the salinity decreases as expected from maximum value at the Bay of

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[1] As of August 31st 2019

Bengal (right side) towards the upstream end (in this case the upper tidal limit near the confluence between Dharkeswar and Damodar/ Mundeswari, in the left side).

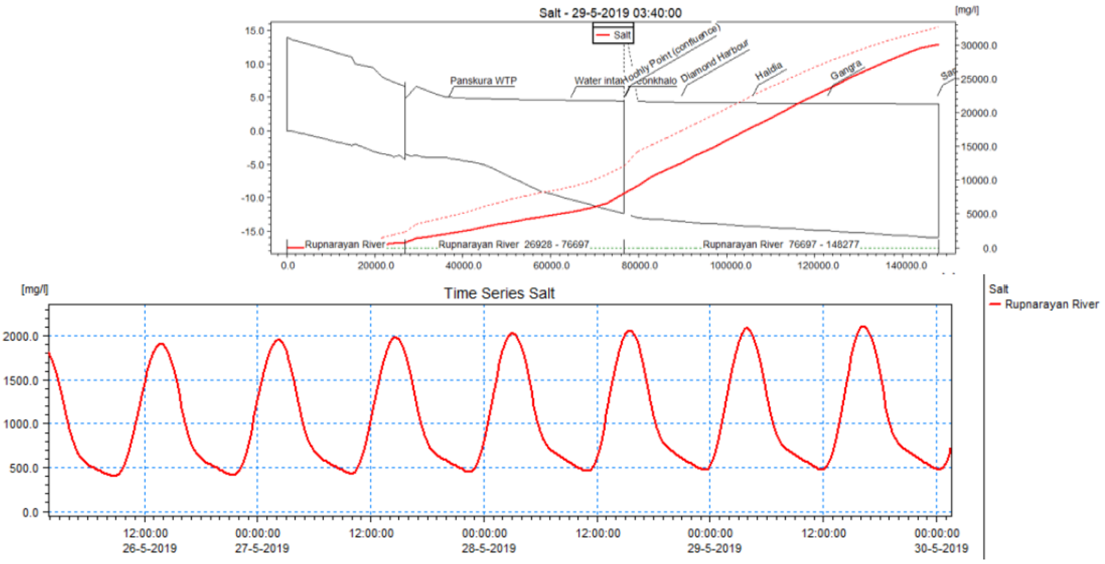


Figure 3-8 The one-dimensional advection-dispersion model simulating the level of salinity. The longitudinal profile of simulated salinity covers the same part of Rupnarayan and Hooghly estuary as in previous figure and has a scale (right side) from 0 to 35,000 mg/l or ppm. The time series below shows the simulated salinity (scale 0-2,500 mg/l or ppm) at Mirpur, the water intake site over a period of 4 days.

Continuous simulation of salinity in the river systems throughout all seasons over a 950 days' (nearly 3 years) period is shown in Figure 3-9. The purpose is to analyse the dynamics and variation from season to season. In the Figure below, the green colour shows when the threshold is never exceeded (condition C), the yellow colour when the threshold is exceeded once during a tidal cycle i.e. at high tide (condition B), and the red colour when the threshold is exceeded throughout the tidal cycle and day (condition A).

According to this pilot model, condition A (always and fully exceeded threshold) covers 2½ months from April to mid of May. Condition B with partly exceedance of threshold at every tidal cycle covers 3.2 months before the dry season and ½ month after the dry season. Finally, condition C (never exceedance of salinity threshold) takes place in half (5.8 months) of the year.

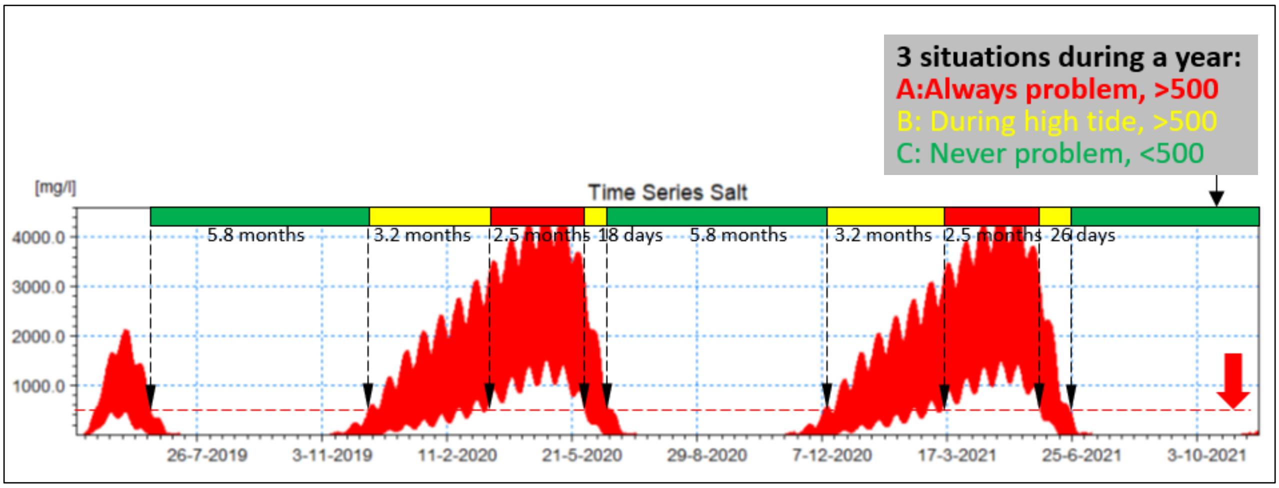


Figure 3-9 Simulation of salinity (in mg/l or ppm) at the water intake site (with not fully calibrated pilot model). The period of time where the salinity threshold limit of 500 ppm is exceeded A) Fully, B) Partly and C) Never is indicated with Red, Yellow and Green colour at the top of the diagram.

The findings about is comparable to the measured salinity levels (Reference /4/) depicted in Figure 3-1 and further illustrated in Figure 3-10.

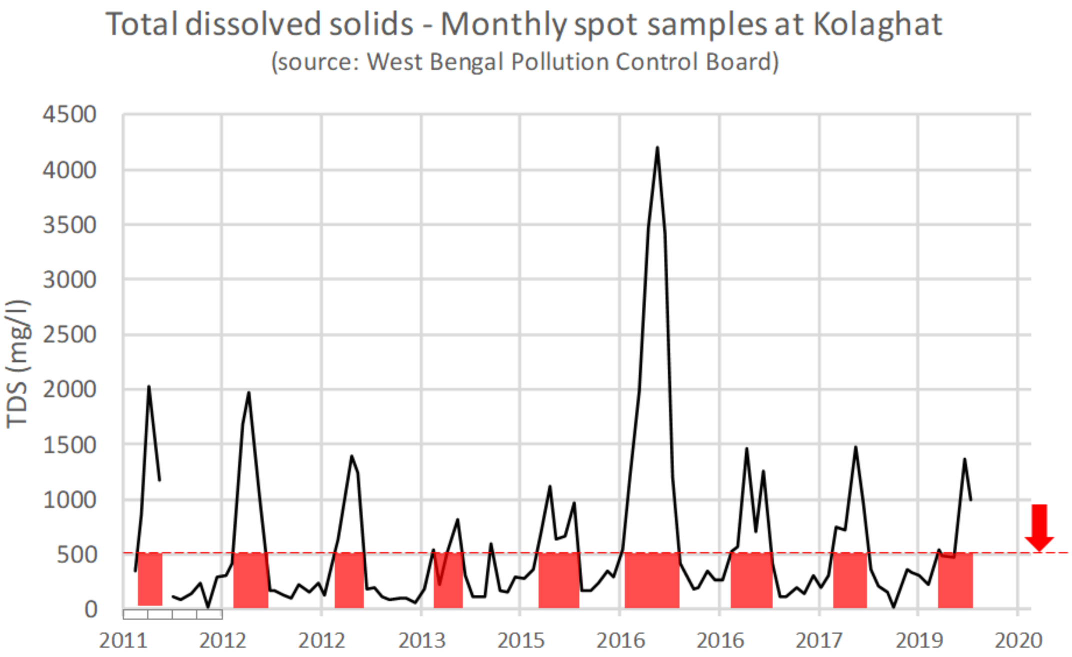
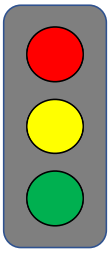


Figure 3-10 Measured salinity levels (total dissolved solids) by West Bengal pollution Control Board at Kolaghat upstream of Mirpur intake site. The figure is based on the same data as Figure 3-1

A fully calibrated regional model, which can be data assimilated and continuously recalibrated with updated measured data of both flow discharges, water levels, and salinity levels will be an excellent tool for providing prognoses for future conditions at and around the intake site, for analysing impact of flow release strategies, effect of drought situations, storm surges due to cyclones, heavy rainstorm events in nearby river basins etc. Such model will take some time to establish.

However, even with the present pilot model, the consistency between measured data and simulated data gives some confidence in defining mitigation measures as described in the following chapter, which must address the following three situations

- **Condition A**. Always and fully exceeded threshold: 2.5 months from April to mid of May.
- **Condition B**. Partly exceedance of threshold at every tidal cycle: 3.2 months before the dry season and ½ month after the dry season.
- **Condition C**. Never any exceedance of salinity threshold: 6.3 months of the year in the monsoon and post monsoon.



4 State Action Plan on Climate Change (SAPCC)

4.1 Review of the State Climate Change Action Plan

The states in India have the primary responsibility to address climate changes. In order to create a coherent national framework, the central government has devised a National Action Plan on Climate Change (NAPCC) which is the basis for the states to develop their specific State Action Plan on Climate Change (SAPCC). West Bengal (Department of Environment) prepared it's SAPCC in 2011, see Ref. /10/.

Climate change is highly relevant to include in the assessment of resilience towards changes in availability of freshwater in East Medinipur: The Ganga (via Hooghly), the Rupnarayan and the Damodar river basins providing freshwater to East Medinipur, are subject to climatic changes in terms of rainfall-runoff patterns. Reservoir storage capacities mitigate climate change impact.

Figure 4-1 The river basins in West Bengal.

Furthermore, East Medinipur is close to the Bay of Bengal, where climatic changes in the occurrence and strength of cyclone storms are important for salinity intrusion during storm events. Sea level rise will influence salinity intrusion as well. In the SAPCC, West Bengal is divided into 6 distinct climatic zones, and East Medinipur (along with South 24 Parganas) is in the so-called Saline Coastal Region. In the report, the Northern region of West Bengal refers to districts North of Ganga, and the Southern region refers to the rest.

Finally, patterns in rainfall, evapotranspiration, and temperature are also subject to changes, meaning that the runoff and freshwater storage to the many low-lying areas and ponds, infiltration to groundwater as well as occurrence of droughts will change.

4.2 Projected climatic changes in East Medinipur

The SAPCC describes projected climate changes in each of the 6 distinct zones separately. Focus has been to consider the Saline Coastal Region in which East Medinipur is situated. The district is characterised by many shallow marshy depressions subject to annual inundation during the monsoon months with nearly permanent wetlands in the shallowest parts. Key conclusions from the report are:

- In winter and pre-monsoon seasons the rainfall has decreased in the Southern region and is projected to continue decreasing in the rest of the century.
- Post monsoon season continues to show an increase in rainfall in the Southern region which will continue. Rainfall in the monsoon is unchanged but is more erratic.
- The onset of the monsoon has been delayed by 1-2 weeks with a corresponding late withdrawal resulting in a general shift of monsoon activities
- There is an increasing trend of tropical cyclonic storms and the frequency of severe cyclonic storms is increasing.
- Both average daily minimum as well as maximum temperatures are increasing and are projected to rise by around 2ºC until 2050
- The average sea level rise has been 1.3 mm per year. Model calculations show it will raise by some 0.4 mm per year in this century.

Even without climate changes, there are severe challenges already today in terms of flooding and droughts every year. Overexploitation of groundwater has caused irreparable damage leading to arsenic, fluoride contamination and saline water intrusion to the groundwater. The SAPCC states “Meeting water demand in the future, even for a business as usual scenario in the mid-century will be difficult”.

4.3 Action Plan for Climate Change Adaptation

Proposed actions in SAPCC is analysed in the following to ensure that any contingency planning to mitigate salinity issues, is well aligned with the already defined action plan on climate change.

The following impact areas have been considered in SAPCC: Water resources, agriculture, biodiversity and forest, human health. For the former, the following actions are envisaged, see the Table below.

Table 3 Action plan for climate change (water resources) from SAPCC West Bengal 2011

Strategy	Institution	Actions
1.Saline Coastal Region		
1.1 Create more water harvesting schemes for accessing sweet water	SAD Department	Rainwater Harvesting Scheme with land Shaping
1.2 Desalination project of river water in coastal areas	PHED	50 schemes each to be completed in 12th and 13th plan
1.3 Surface water treatment plants	PHED	20 schemes to be completed within 12th and 13th plan
1.4 Reconstruct the Sundarbans embankment in vulnerable areas. The major funding is from the central government and the World Bank	IWRD SAD Panchayat Dept.	i. Through public and private partnership to entrust the management of the embankment to public as well. ii. Undertake stabilisation of embankment slope, and iii. Create drainage through the embankment to drain out high tide water.
1.5 Construct sluices to prevent the intrusion of saline water in channels where it does not exist	IWRD	i. Identify the channels ii. Fix the sluice gates
2.Scientific Assessments		
2.1 Establish high resolution weather monitoring, river inflow monitoring, hydrograph monitoring, and early warning system for floods	IWRD WRIDD SAD IMD	i. Undertake study to understand the spatial resolution required to monitor rain fall and river inflow data ii. Install automatic weather monitoring including rain gauge and water gauge stations at appropriate spatial resolution within all 23 Basins of West Bengal iii. Install hydrograph stations at high spatial resolution across the coastline ii. Install doppler radars (at least 6 for 6 regions) for an overall coverage of the atmospheric parameters iii. Create scientific capacities in the state to undertake real time analysis and hence near and long-term forecasting of extreme rain fall and onset of monsoon and iv. Dissemination systems to make all farmers and the entire population aware of the impending events
2.2 Assess water availability by region, assess current demand of water by sector and future demand by sector by factoring in Climate change for short, medium and long-term timelines	IWRD WRIDD PHE DIC	Undertake modelling activity, assess demand of water by sector using climate change projections and its impacts on water availability
2.3 Monitor quality of water to understand the impacts of warming of the atmosphere and for providing remedies	PHED, WRIDD	i. Underground water quality ii. Surface water quality iii. Upgradation of water quality labs as per CPCB norms
2.4 Identify vulnerable areas of ground water contamination by point sources of industrial, municipal solid waste landfills and agricultural pollutants	WRIDD	Idle
2.5 R&D on contamination Mitigation Devices (Model Study)	WRIDD	Idle
2.6 Map water availability, Minor surface water bodies, Aquifers in time and space, and water use in conjunction with land use and land classification	IWRD WRIDD	idle

3.Policy related strategies		
3.1 Modernization of Irrigation system using Drip, Sprinklers systems	SWID, WRIDD, Agriculture Department	i. Undertake feasibility studies ii. Implement
3.2 Introduce pricing regulation for use of piped water for domestic use and drinking water	PHE	i. Feasibility studies ii Implementation
3.3 Undertake periodical census of medium and minor irrigation projects to check sustainability and also to detect dis-functionalities and implement remedial measures	IWRD	i. One survey in 12th plan ii. One survey in 13th Paln
3.4 Introduce variable water tax for irrigation purpose on both use of underground water and surface water sources in the short term and in the long-term metering of water usage may be done obtained from canals as well as from centralised underground sources	IWRD WRIDD	i. Study on pricing structure keeping in view the potential of payment of the different farmer categories
3.5 Extend compulsory rainwater harvesting regulations for all houses in cities and town in WB	SWID Municipal Corp. of towns and cities	i. Design to be developed for different housing types in different regions ii. Create incentive schemes for the same iii. Implement 25% of all towns in WB

A couple of action points emphasize water harvesting (action 1.1 and 3.5). However, this is mostly applicable for local decentralised solutions on household level as centralised bulk water transmission requires a large, robust concentrated source of water. Desalination is mentioned as a solution (action 1.2) in the SAPCC and is also considered among possible mitigation solutions in this project. Another solution mentioned (action 1.5) which is also considered herein is construction of structures (sluice gates) to prevent saline water from entering channels which should be with freshwater only.

Provision for monitoring, modelling and early warning of flow and floods is highlighted as an action point (2.1). Interestingly, it takes it a little further than considered in this project: “long-term forecasting of extreme rainfall and onset of monsoon”. Long-term forecasting (also called seasonal forecasting) is a very good idea. Conventional forecasting, which will typically cover up to 5 days (the reliability of weather forecasts) could be further extended with so-called ensemble forecasting and seasonal forecasting to generate stochastic forecasts of flood levels and associated contingency planning. It is, however, a step of complexity above conventional forecasting, which should be the first step.

Mapping (action 2.6) and assessment (action 2.2) of water availability in space and time with proper matching with the current water demand from different stakeholders is also highly relevant for establishing a mix of water sources which jointly will meet the demand.

One point, which seems to be missing in the list of action plans on climate change, is the provision and maintenance of adequate storage capacity through reservoirs and their proper maintenance (avoidance of siltation etc.) as well as policies on sharing of storage capacity and water. A complex management system is needed which keeps track of water availability and storage capacity in space and in time at all times for better water sharing/water storage sharing.

5 Contingency solutions

5.1 Salient features of the new Water Supply Scheme

The scope of work under this package for the district of Purba Medinipur of West Bengal encompass extraction of 112 MLD Raw water from river Rupnarayan near Mirpur by means of a pumping system located on an intake jetty, housing vertical turbine pump sets. The raw water is conveyed through 1400 mm diameter MS pipe for 18 km to the Primary Settling Pond located at the Water Treatment Plant at Nandakumar. The supernatant water is then pumped through vertical turbine pumps to the conventional Water Treatment Plant and treated water is pumped through Horizontal Pump sets to the secondary rising mains of varying diameter to the Ground Level service Reservoirs(GLSR), located at Nandakumar, Chandipur, Nandigram I and II. Presently water will be pumped to GLSR of Nandigram I and II, but provision has been kept feeding the GLSR at Nandakumar to Chandipur in the future. Salinity issues will make it inconvenient to pump raw water for

- Some hours per day around high tide for certain months
- Some days, weeks or months during the dry season

5.2 Sketch of solution options

Six basic solutions identified, listed below and discussed in the following. The list or description of each option is by no means exhaustive but serves as a starting point for further exploration of the most feasible short, mean and long-term solutions in in-depth studies. Options may also be combined.

1. **Timing:** Intelligently monitor and manage the timing of pumping between different storages depending on the tide, the vertical and horizontal mixing of brackish water, diurnal demand
2. **Storage:** Store water in buffer reservoirs (day, week or season reservoirs, recharge to ground water aquifers, utilise fishponds, reclaim area along river bank)
3. **Conveyance:** Long-distance transmission lines of freshwater from upstream to the site (pipelines from upstream intakes, barrages or reservoirs)
4. **Groundwater:** Use groundwater (tube-well ground water) as a backup when surface water is too saline for a longer period of time
5. **Prevention:** Use of barrages and similar barriers in Rupnarayan to avoid upstream saline water propagation and to avoid mixing of fresh and saline water
6. **Treatment:** Remove salt in the WTP by desalination (only a side stream, equipment for treating brackish water and not ocean water, brine to be diluted in main river during ebb)
7. **Upstream water release:** Enter into dialogue concerning water release from Farakka barrage, Durgapur and other upstream dams during the lean season
8. **Service level non-compliance:** Acceptance that 500 ppm can be exceeded few weeks per year, as IS:10500 has provision for tolerable limit up to 2000 ppm if no alternative exists

In Panskura-II water intake, solution (1) and (2) is applied today. In Geonkhali water intake, solution (1), (2) and (4) is applied. Local conditions determine the best options. Also, long-term climatic changes must be considered. The following sections give preliminary sketches.

5.2.1 Timing by Smart Water Management

If there is enough storage capacity in the bulk water system including overhead tanks to store 24 hours of water consumption (“day”-reservoirs), a good and cheap solution is to pump raw water only during few hours in the ebb/low tide period every day when the salinity is below the critical threshold (Condition B, yellow zone).

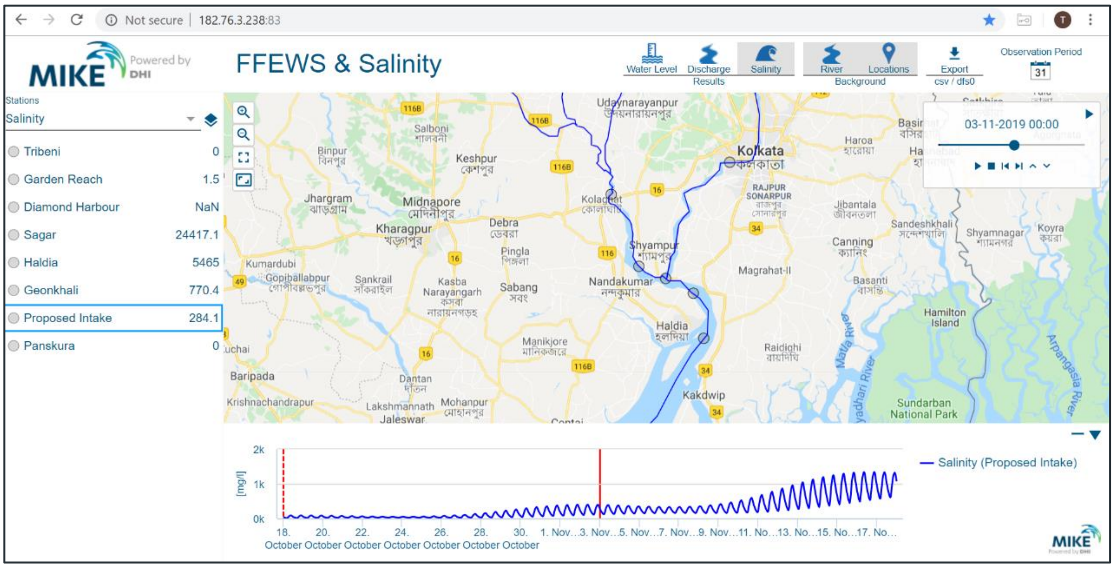
If storage capacities for a few days exist downstream (“week”-reservoirs), it could be useful also to consider pumping more during neap tide and nothing during spring tide (where salinity is higher, in Condition A, red zone). Ideally, the week-reservoirs should be full before the start of the one-week spring tide period which occurs twice every month.

The closer to the Summer/dry season, the narrower becomes the window of operation for pumping raw water during low tide and during neap tide. However, as the salinity is strongly depending on the freshwater flow, it may be possible also to agree with upstream reservoir operators (in DVC) to release more freshwater during times where salinity is already low and less freshwater, when saline water dominates anyway and prevents raw water pumping. In the latter case, upstream release of freshwater will be “wasted”. Thus, a flow release can be timed to get the most benefit out of the additional freshwater from upstream.

Under certain conditions, there may be a larger vertical gradient of salinity, meaning that water abstraction should take place closer to the surface. As the water surface is moving up and down with the tide, certain mechanical arrangements (floaters) for the intake will be required.

Similarly, the horizontal mixing may also be different with higher salinity along the right bank under certain flow conditions than along the left bank. Shifts from between different intake locations could also prolong the window of operation.

Use of sensors, hydraulic and salinity modelling and data analyses will be an excellent “smart water” approach to utilise freshwater access to “the limit”. Figure 5-1 below shows an example of a newly developed cloud-based dashboard of observed and forecasted salinity levels near the water intake.



Stations
Salinity

Station	Value
Tribeni	0
Garden Reach	1.5
Diamond Harbour	NaN
Sagar	24417.1
Haldia	5465
Geonkhali	770.4
Proposed Intake	284.1
Panskura	0

Observation Period
03-11-2019 00:00

Figure 5-1 Example of a cloud-based dashboard (pilot version under development) for monitoring and smart water management of salinity near the proposed intake location.

5.2.2 Storage

Additional storage capacity is essential if there is a need for a buffer system. The necessary buffer can be for few hours (“day”-reservoirs), for few days (“week”-reservoir) or for weeks or months (“month”-reservoir). Considering the projected raw water extraction capacity of 112 MLD, this corresponds to the following sizes of each type of reservoir options:

- Day-reservoir: 112 ML (million litres= 112,000 m^3=112 OHRs each 1000 m^3 = 200 x 200 x 3m pond = occupying 4 ha assuming 3 m depth (the size of the projected pre-settling pond at Nandakumar is 4 x 98m x 90m x 6m i.e. 210,000 m^3 or nearly two days of storage)

- Week-reservoir: 1,000,000 m^3= 600 x 400 x 4 m pond = occupying 24 ha assuming 4 m depth (This is approximately the size of pond at Geonkhali WTP)
- Month-reservoir (4 months): 15 mio m^3=15 ponds each 600x400x4=one 3000x1000x5m = occupying 300 ha assuming 5 m depth

Several lowland pond areas exists in East Medinipur. Near Garsafat in Moyna block 20 km West from Midpur, the landscape has changed as shown below over the last few decades. Dozens of ponds each approximately 500m by 500m (25 ha) have emerged. The use and the value of these ponds are not clear but could be converted into freshwater ponds.

Figure 5-2 Lowland (aquaculture) ponds in Moyna block, 20 km W of Mirpur water intake

A quick digitalisation using Google satellite imageries is shown in Figure 5-3 below. Also other sources of imageries were tested, i.e. satellites from European ESA, Japan Space Agency JSA i.e. Sentinel (10 m spatial resolution), Landsat-8 OLI+PAN (15 m spatial resolution). A detailed remote sensing survey with pre- and post-monsoon imageries can be done for more accurate mapping of the surface the water ponds (artificial or natural) and fishpond aquaculture facilities if needed. For the purpose of this screening, this will be enough.

Based on the GIS digitalisation, the following table of pond areas have been prepared. It is remarkable to see the area of ponds. In recent years, aquaculture has become a highly profitable business in West Bengal, and many low-lying areas have therefore been converted into artificial fishponds as also indicated in Figure 5-2. In Figure 5-3 below, it appears that it is especially along Haldi River, that water is diverted into such fishponds.

Table 4 Area of ponds within certain distances from intake

Type of Ponds	Area Within 25 Km Buffer from Proposed Intake Location (Sq. Km)	Area Between 25 km Buffer to 40 Km Buffer (Sq. Km)	Total Surface Water Ponds Area (Sq. Km)
Natural Lakes / Ponds	2.288	1.704	3.992
Artificial Ponds / Fishponds	165.746	23.234	188.980
Total Area (Sq. Km)	**168.034**	**24.038**	**192.972**
In hectares	**16803**	**2404**	**19297**

For understanding the scale, the following example is established: 15 million m^3 corresponds to 4 months storage volume for a WTP producing 112 MLD as discussed in the previous page. If all 16803 hectares (equivalent to 168 million m^2) could be used, this corresponds to just 10 centimetres extra depth in all ponds!

A couple of challenges is:

- Fishponds may be in risk of drying out in the lean season and will be in need of water at the same time as when water is required by PHED for drinking water production
- Private fishpond owners and/or operators may not be willing to trade water with PHED, or it may be too cumbersome to come to an agreement between the two parties

New opportunities are, however, also appearing:

- As discussed above, the artificial fishponds in Figure 5-3 are located near the Haldi River because they need supply of freshwater from that river. There are not that many artificial fishponds along Rupnarayan River which is probably due to non-availability of freshwater sources from there, as Rupnarayan River is partly saline.
- However, PHED might provide water (like to any other industry) through pipelines to new fishpond operators who want to convert land close to Rupnarayan/ intake into profitable aquaculture against a commitment the other way around to draw water from the same fishponds during the lean season if/when needed. PHED helps to create new business and solves at the same time the need for buffer storage capacity.

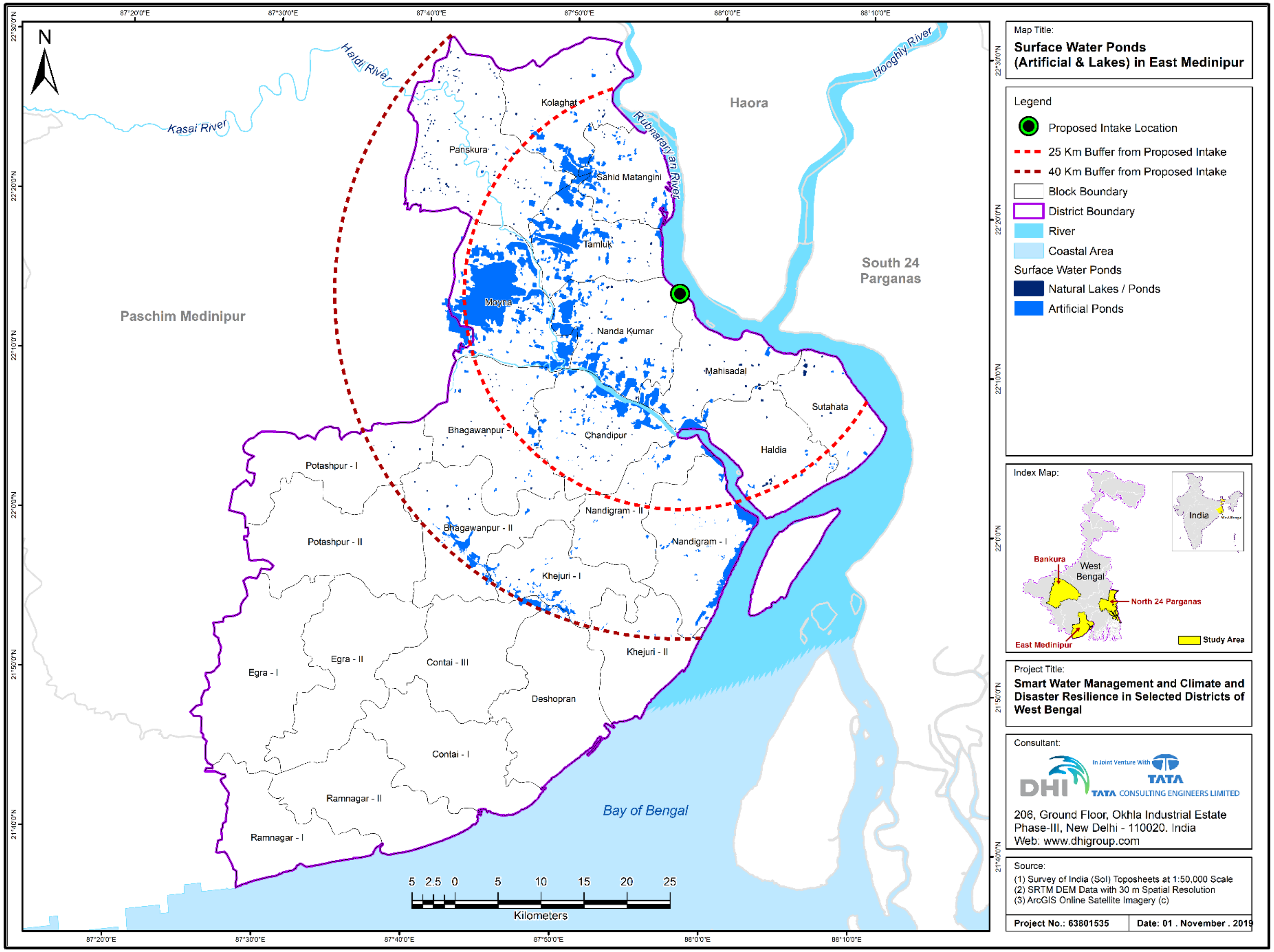


Figure 5-3 Maps of pond areas in East Medinipur within 25 km and 40 km, respectively, from the proposed intake location in Rupnarayan River

Another opportunity is to consider reclaiming reservoirs along the right (Western) Rupnarayan Riverbank, see the figure below. Area A South of Tamluk city covers 230 ha and used to be land in 1994 but is now eroded and part of the river. Area B is North of the Mahishadal-Geonkhali Road covering 270 ha and is today land (mud flats) but used to be submerged. There is even a good opportunity to expand the reclamation North of area B. The solution is feasible for different reasons:

- It is at the Rupnarayan river itself, and construction work is limited to construction of an embankment (each area 3-4 km length) and gates and pump station for connecting the reservoirs with the rivers when the salinity level is below critical limits
- Pre-settling of suspended sediment can take place in the reservoir to reduce turbidity and the wear of pumps and inner lining of pipelines. Maintenance by dredging or pumping settled sediment and dumping it in the Rupnarayan River is simple.
- The storage capacity is very big and will ultimately solve the issue of climate change vulnerability many years to come.
- With proximity to both Panskura and Geonkhali, these WTP could also be connected through pipelines to this (these) raw water reservoir(s) for enhancing their capacities.
- Satellite imageries from different years reveal some adverse river morphological activity with erosion and accretion of land, which could pose a risk to infrastructure and housing along the riverbank. Construction of reservoirs could be integrated to a bank erosion as well as flood protection solution and thus serving multiple purposes.

Figure 5-4 Two possible sites for area reclamation for reservoirs. Area A (near Tamluk, today submerged) is 230 ha, area B (North of Mahishadal-Geonkhali Road, today mudflats) is 270 ha. The left figure shows a satelite image from 1994, the right is from 2019.

5.2.3 Conveyance – long-distance transmission lines

Transmission of freshwater in main pipelines (e.g. diameter 900 mm) from upstream reservoirs will ultimately provide a solution. As described in the Inception Report, Ref. /9/, Damodar Valley Corporation (DVC) operates and maintains 4 major dams (Konar dam, Tilaiya dam, Panchet dam and Maithon dam) and 1 barrage (Durgapur barrage) on Damodar river and its tributaries for flood control, irrigation water supply and hydropower.

A supply demand for the considered scheme in East Medinipur of 112 MLD is equivalent to 1.3 m^3/s, and therefore modest to other water usages. The problem is, that once the flow is coming “freely” in the river, it is being contaminated with saline water when reaching the Rupnarayan estuary. A direct pipeline parallel to (or in the riverbed, see the cross-section profile in Figure 5-5) the river from an upstream reservoir or barrage will mitigate that problem. If the pipeline is in the river itself, it needs protection against bed scour around. This is illustrated in Figure 5-5.

A large project for constructing additional reservoir storage capacity for irrigation purposes as well as for flood control purposes is currently under preparation (under National Hydrology Project co-financed by the World bank). As part of such projects, a pipeline for domestic water supply for the downstream part of West Bengal could be considered.

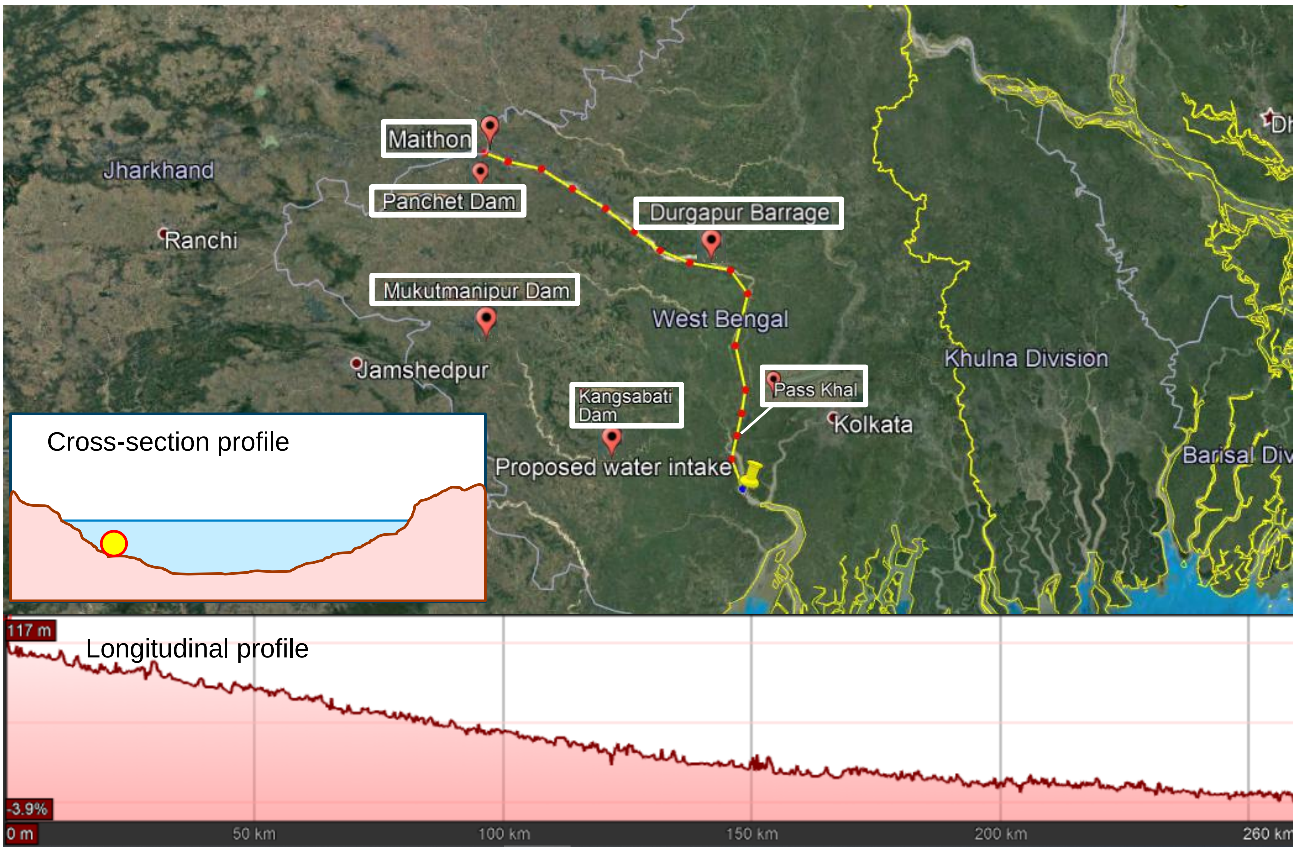


Figure 5-5 Example of a long-distance (230 km) transmission line from Maithon dam (230 km), Panchet dam (230km), Durgapur Barrage (170 km), Mukutmanipur dam (160 km) or from Kangsabati dam (70m).

The possible nearby raw water sources are Maithon dam, Panchet dam and Durgapur barrage, all along Damodar River and Mukutmanipur dam and the Kangsabati Dam along the Kangsabati river (see Figure 5-5). An existing canal Pass Khal connecting the lower Damodar discharging into Hooghly river and the Mundeswari discharging into Rupnarayan river is also noted in Figure 5-5. The purpose or history of this canal is unknown. It does provide an opportunity to manage how much freshwater flow is going into different parts of the river system near the intake site.

Durgapur barrage is the raw water source for two other project blocks Mejhia and Gangajalghati in Bankura district under WBDWSIP.

Another possibility in the longer run (10-20 years perspective) is to conjoin road and bridge connectivity planning with water infrastructure connectivity. In contrast to Rupnarayan River, the Hooghly River is (due to its connectivity with Ganges River) without salinity already few kilometres from the confluence with well-functioning water intakes at water treatment plants near Kolkata. The state highway SH15 from Kolkata can connect with Haldia and the Southern part of East Medinipur if a bridge is constructed along the existing Gadiwara - Geonkhalo ferry route across the Rupnarayan-Hooghly confluence, see Figure 5-6.

Figure 5-6 Example of long-term road connectivity combined with water connectivity planning.

Combing a bridge crossing for road connectivity and water pipeline connectivity, the length of a water pipeline from Kolkata to Mirpur (proposed water intake location) could probably be reduced to say 60-70 km.

5.2.4 Dilution using groundwater or other water resources

The solution at Geonkhali has been to mix saline surface water with freshwater from 14 tube-wells (producing around 9 MLD). A similar solution could be sought in this location. A precondition is, however, that the groundwater is not polluted with saline intrusion.

The availability of suitable aquifers (through proper geohydrological studies), the water quality of water from existing ground water wells in the areas, acquisition of land for construction of pumphouses and tube-wells, and costs of acquisition and operation of large pump systems need to be considered for the feasibility. A brief analysis is presented in the following, which is partly a summary from Ref. /11/.

The Central Ground Water Board CGWB presents a brief description of groundwater resources in West Bengal. According to Ref. /12/, the yielding of groundwater near East Medinipur is around 150 m^3/hr, but there are groundwater quality issues to be considered (salinity, and iron). Ref. /11/ summarises this: “The effect of salinity in ground water, has increased over the years, and efforts to check this will possibly be one of the biggest challenges and made more difficult with rising sea water levels and global warming”. A profile description of groundwater resources in East Medinipur is available at the CGWB (see Ref. /13/) although some years old. Near the coastal zone, the groundwater in the near surface shallow aquifer is saline and fresh water is only found at a depth of 120-300 m below ground level and groundwater development can only be done through deep tube wells. The blocks Tamluk, Nandakumar, and Mahisadal along the Rupnarayan River as well as Nandigram-I, Nandigram-II and Chandipur in the vicinity of the proposed water intake, are all in this category, see Figure 5-7.

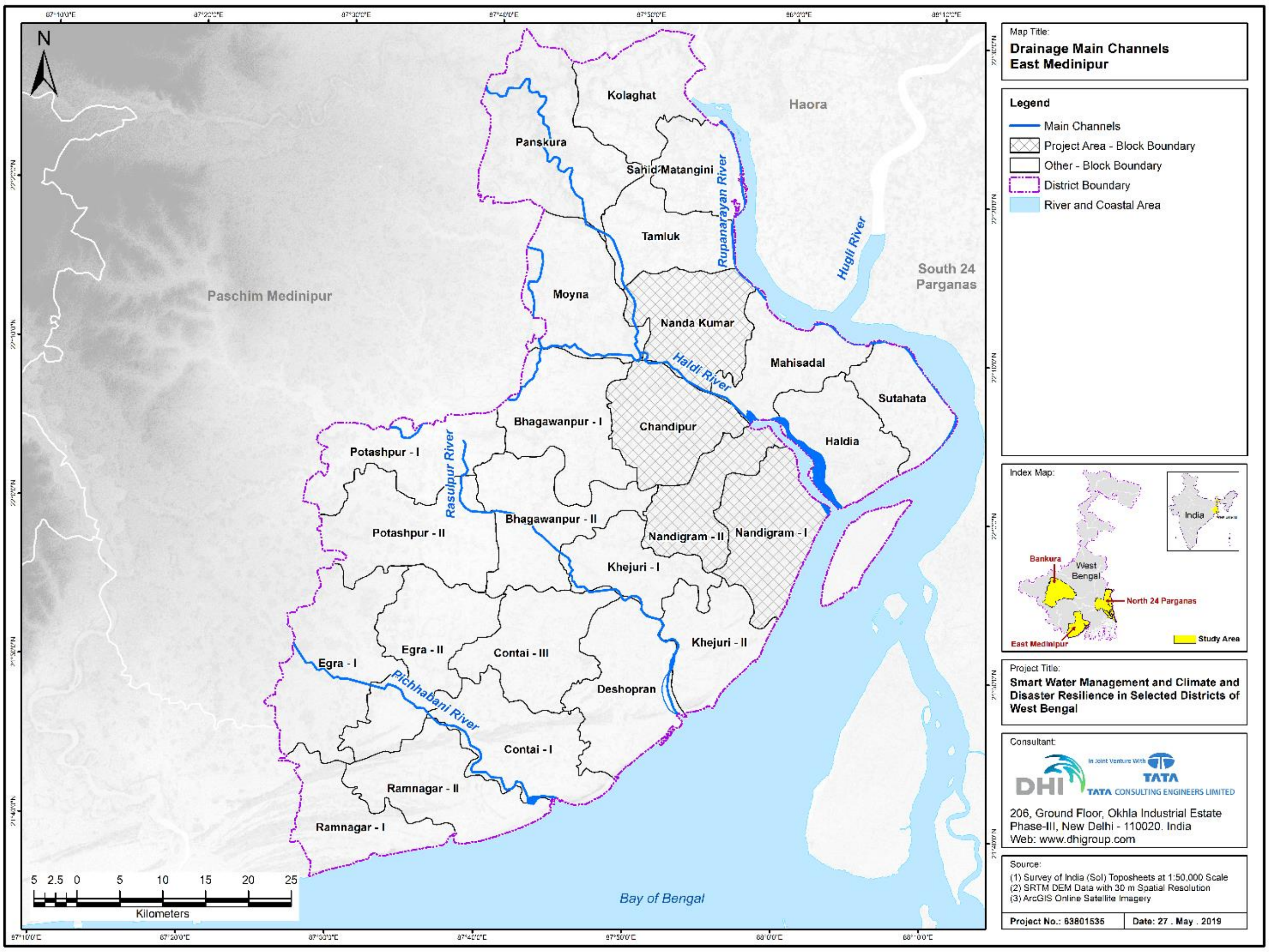


Figure 5-7 Blocks and rivers in East Medinipur.

The ground water in the coastal area occurs under semi-confined to confined condition, Ref. /11/. CGWB has evaluated the quantum of sub-surface outflow of groundwater through the deeper confined aquifers in the coastal blocks, see Table 5, which sums up to 20 MCM per year. For comparison, the daily water intake to the WTP of 112 mld corresponds to 40 MCM per year, i.e. this can meet six months' supply.

Table 5 Sub-surface outflow of groundwater from coastal blocks (from deep aquifers), table 2-9 in Ref. /11/

Sl.no	Block	Average Transmissivity (T) (m2/day)	Average Hydraulic gradient (I)	Maximum length of flow path (L) (km)	Annual ground water flow in (MCM)
1	Tamluk and ShahidMatangini	2000	1: 3294	20.27	4.492
2	Mahishadal and Nandakumar	2000	1: 5068	16.22	2.336
3	Sutahata and Haldia	2000	1: 4300	17.74	3.012
4	Nandigram-I, II and Chandipur	2000	1: 5447	17.74	2.377
5	Kheiuri-I &II	2000	1: 6000	14.19	1.726
6	Contai-I,II & III	2000	1: 5068	26.35	3.795
7	Ramnagar-I & II	2000	1: 6586	21.79	2.415
				Total	**20.150**

The existing groundwater exploitation in Tamluk, Mahishadal, Sutahata, Haldia and Contai-III blocks has already exceeded the subsurface outflow of ground water through the deeper aquifers (Table 5) meaning that the availability of groundwater is limited. However, some of the existing groundwater tube wells will be redundant after the surface water based water supply scheme is in place, and could be converted into backup systems.

Other sources of water

Besides from groundwater other sources of water could be treated wastewater from existing urban drainage systems. Traditionally, this is difficult to accept for consumers worldwide although treated wastewater is literally much cleaner than untreated surface water from rivers in many places. A condition for use of wastewater is, however, that it is collected and secondly that it is treated in a sewer treatment plants. None of this is the case in the project area and sewerage systems do not exists. In the future, it may occur.

Rainwater harvesting is not considered as an option. The reason is, that at the time where water is in need, there is also no rain. Rain-harvested water from other times of the year need to be stored in reservoirs, which leads to solution option number 2 (buffer storage capacity).

5.2.5 Prevention of saline mixing using a barrier

Mixing of freshwater and saline water and propagation of the tidal wave up through Rupnarayan can be prevented by means of a barrage. In the Gulf of Khambat in Gujarat, the Kalpasar barrage has been discussed for years. This project would be a much smaller one. Instead of a 30 km wide dam, a 3 km wide barrage across Rupnarayan upstream of the Hooghly river confluence would be needed. It could be combined with a road or railway connection across the estuary. The main drawback besides from costs would be the environmental impact. A less intrusive solution would be to construct a submerged weir, which allows water to pass but through a much smaller and reduced cross-section, see the Figure below.

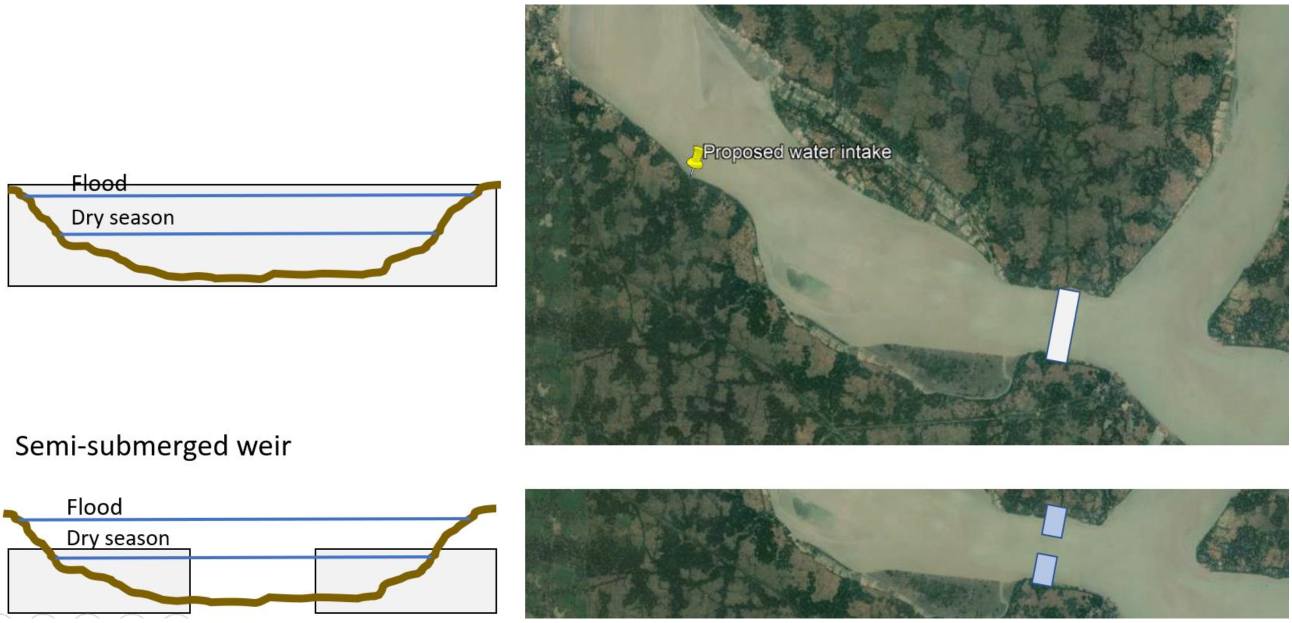


Figure 5-8 Example of the layout of a barrage or semi-submerged weir in Rupnarayan river.

5.2.6 Treatment by desalination

Establishment of a desalination plant which will treat part of the water (enough to dilute the other untreated part) is an ultimate solution which is scalable and flexible. Unfortunately, it is also a costly, and not least complicated solution to maintain.

The operation is, however, less costly than a desalination plant for treating seawater which has a much higher salinity (35,000 ppm). Assuming that the salinity level of brackish water is 3,500 ppm, the energy required in the reverse osmosis process would roughly speaking be 10x less, and the fouling of membranes would be 10x less. The brine (waste product of very high salinity) would have to be discharged back into the river at ebb tide, so that the brine flow would be brought downstream and diluted in the estuary before the tide reverses.

Figure 5-9 Desalination of brackish water by conventional RO membranes.

A central brackish water desalination solution seems to costly and complicated, but in the future, it may become a possibility.

It should be noted, though, that desalination can come at many different scales. RO (reverse osmosis) membranes are the core technology in desalination, and RO-technology is also applied in minor water ATM machines serving a few dozens of people as well as in water purifiers in middle-class households

Figure 5-10 RO membranes application for water purification at different scales.

5.2.7 Release of Water from Upstream Reservoirs

Damodar Valley Corporation (DVC) operates and maintains 4 major dams (Konar dam, Tilaiya dam, Panchet dam and Maithon dam) and 1 barrage (Durgapur barrage) on Damodar river. The flow in the lean season is regulated and shared between competing stakeholders. Most of the water goes to irrigation. By releasing more water downstream, which will eventually reach the Rupnarayan river, the window for pumping water without salinity becomes wider.

To illustrate the impact, a pilot sensitivity simulation was carried out: The assumed discharge from Mundeswari-Damodar River is depicted below. Within the interval from 20/12 2019 to 20/6 2020 of the hypothetical timeseries, it is assumed that discharge will not go below 150 m^3/s.

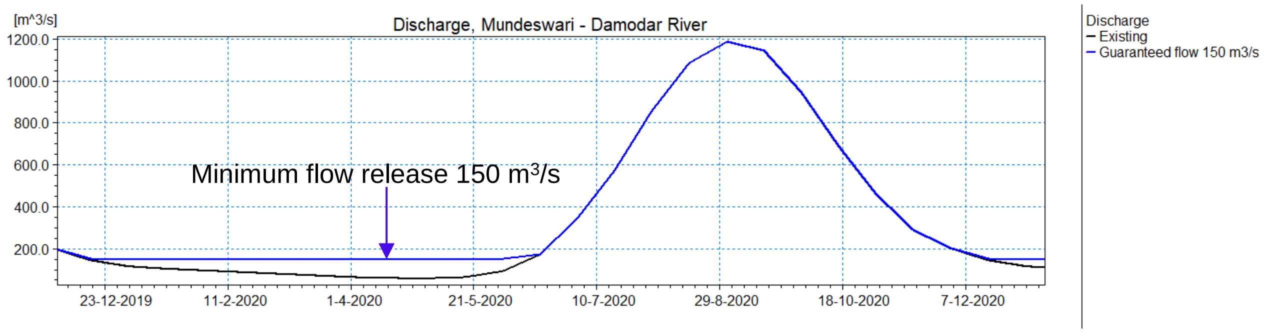


Figure 5-11 Test simulation of a hypothetical hydrograph as an illustrative example of the impact of a guaranteed minimum release of 150 m^3/s (blue line) from DVC as compared to a minimum discharge down to 60 m^3/s (black line).

Differences in simulated salinity with the two hydrographs in the figure above is shown below in Figure 5-12. The same time interval covering approximately one year is shown, together with three selected zoom-in time intervals each covering 3 days.

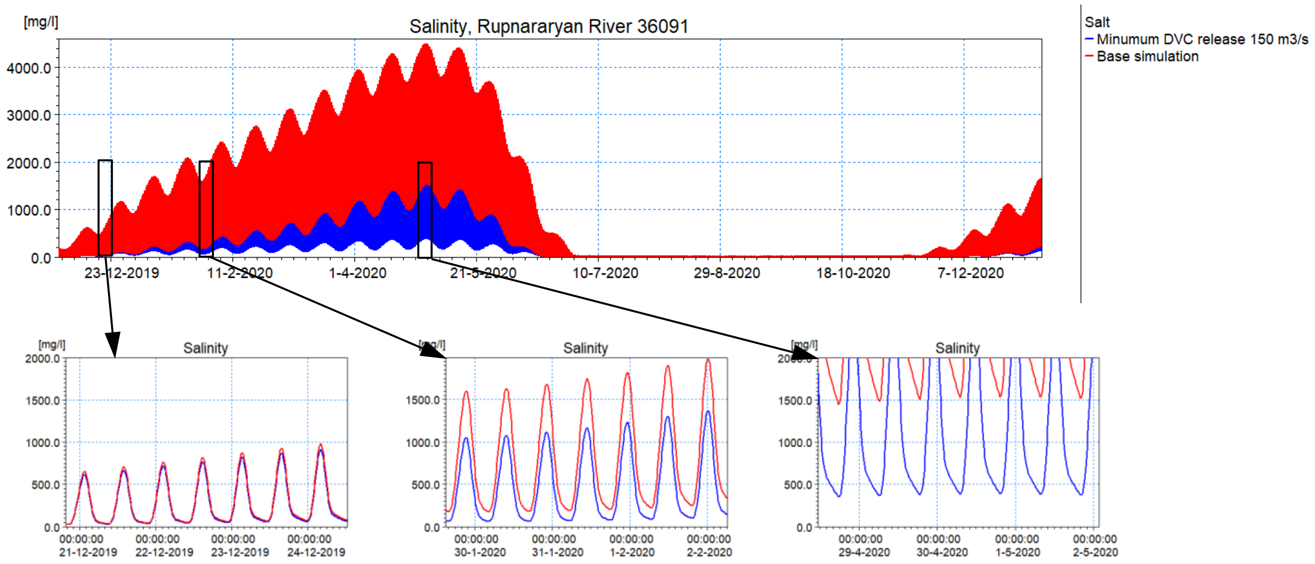


Figure 5-12 Simulated salinity in the base scenario without a minimum discharge (red line) and the minimum flow release scenario assuming minimum 150 m^3/s (blue line).

The pilot sensitivity simulation indicates that with a minimum release, it is possible to achieve salinity levels below 500 mg/l in all tidal cycles throughout the year. A fully calibrated model is required for precise quantification. The above is a hypothetical example only. In reality it may be unlikely to have a guaranteed flow release of 150 m^3/s as the water availability is already very scarce during the dry season, and DVC is unlikely to issue flow release guarantees. In the future, with more storage capacity available in the upstream reach, it may be more likely.

5.2.8 Shift of Water Intake Further Upstream

The proposed water intake is located at Mirpur, which is in between the existing Panskura water intake 28 km upstream, and Geonkhali water intake 12 km downstream. Figure 3-2, Figure 3-3 and Figure 3-4 show salinity levels at Panskura. Recent detailed data from April 2019 shows that even at Panskura, the salinity levels exceeds 1000 mg/l (ppm). Therefore, the same problem with too high salinity levels exist 28 km upstream. Furthermore, the extent of the salinity intrusion may further change in the future due to climate change and/or change in upstream water management. Therefore, shifting of the water intake is not considered a viable option.

5.2.9 Service Level Compliance

The Indian Standard of drinking water quality (see Ref. /15/) specifies that the permissible limit of salinity (total dissolved solids TDS) is 500 ppm, but that the “*Permissible limit in the absence of alternate Source*” is 2000 ppm. One may argue that during the critical time period in the dry season (condition A, red zone), there is no alternative source. Water with salinity up to 2000 ppm will not cause health hazards if only consumed in a short period of time.

By considering the salinity measurements in previous chapters, it is noted that the period each year of red, yellow and green zones for exceedance of tolerance limits will change dramatically if the limit is changed from 500 to 2000. The time in Condition A, red zone (exceedance of limit throughout one tidal cycle) will be limited.

Another key observation is, that 70 lpd is guaranteed but each person would actually require less than 3 lpd of drinking water quality as the rest is used for washing, cleaning, flushing etc. This 3 lpd could be provided by other means such as:

- Time variation of managed TDS level (salinity) in the piped water supply. During critical periods in the dry season, consumers will get a SMS in case the water quality will be varying over the day. The water of optimum drinking water quality (salinity/TDS less than 500 ppm) will be available in the pipe connection from say 7am to 8pm, see Figure 5-13.
- Such a variation in time requires that there is a separate dedicated tank besides the OHT overhead tank with high-quality drinking water (<500 ppm), and a valve which will switch between low-quality (<2000 ppm) drinking water to high-quality during those two hours, see figure below.
- The source of high-quality drinking water could be from a local RO-membrane as shown in the Figure, or a pipeline from a dedicated high-quality drinking water OHT which serves different zones. Examples exist from e.g. Chennai, where the source is a water tanker.
- Free access to a public Water ATM facility with drinking water quality and shared within a village during the limited period with Condition A, red zone of the central water supply

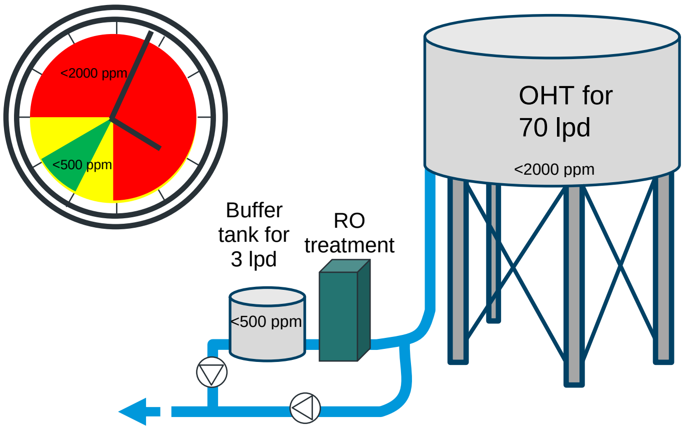


Figure 5-13 “Smart water” notification by SMS to consumers regarding changes in service levels when salinity levels change over time. High quality for minimum 3 lpd is managed by running drinking water supply through RO-membranes for polishing and removal of high TDS contents.

The first three options may, however, not be feasible to manage in practice. The fourth option is the simplest. The key solution is to have a facility (an app managed by Gram Panchayats) to provide information to consumers about the service level. By having such transparency about the service level, temporary lowering of such service level will be much more acceptable to end consumers.

5.3 Cost Estimates

Rough estimates of costs are provided in the following table. Technical and financial (pre-) feasibility studies are required for more accurate estimates. This, the following serves only as cost indications to enable ranking of solution options based on costs.

Table 6 Costs estimates of solution options

Solution Option	Description	Unit Costs Assumption USD (INR)	Total costs USD (INR)
1.Smart Water Mngt.	Extended flow and storage forecasting system, sensors etc.	Lump (assuming all SCADA/instruments in place) USD 1 mill.	Lump USD 1 mill. (INR 7 cr.)
2.Buffer storage	Reservoir of CWR quality	Per kl (kilo litre) USD 30 (INR 2100) 1 GLSR (10 ML) USD 0.3 mill. (INR 2.1 cr)	10 days buffer = 112 GLSRs USD 33 mill. (INR 230 cr.)
3.Transmission lines	Long-distance pipeline - 900mm. 900 mm DI MS pipe with epoxy coating and lining 8mm thick	Total cost (including all item of works related to pipe laying). Per m: USD 250-300 INR 20,000 per m USD 500-600 INR 35,000-40,000	100 km transmission line USD 30 mill. (INR 200 cr.) Pumping station, lump USD 0.5 (INR 3 cr.)
4. Backup w. groundwater	Tube well - Assume 300x150mm casing and strainer pipe, pumping capacity 180 m^3/hr=4.3 mld, depth of 300m for fresh layer of water Assume 60 mld for backup, i.e. 14 tube wells	Per tube well ($180m^3/h$), Drilled depth per m: USD 14 (INR 1,000) For 300 m: USD 4200 (INR 300,000) + Pump, power, tank USD 4,200 (INR 3,00,000)	14 tube wells USD 0.11 mill. (INR 0.8 cr.) 10 km transmission lines USD 8 mill. (INR 40 cr.)
5.Barrage /sluice gate to reduce intrusion	Comparison to Vykuntapuram barrage Ref. /14/, on Krishna River, 1190 m wide	Vykuntapuram barrage projected to cost 2,169 crore, including the land acquisition cost component of `700 crore to `800 crore	Lump USD 140 mill. (INR 1,000 cr.)
6.Desalination	Comparison to Minjur Seawater Desalination Plant, Chennai. 100 MLD from pure Seawater (30,000 mg/l)	The RO-based plant costs INR 515 cr in 2010, and produces 100 mld	Lump, ½ the size of Minjur USD 40 mill. (INR 280 cr)
7.Additional release of water from upstream reservoirs	By negotiation with DVC (and other) reservoir operations,	No cost, but water is scarce and unlikely to be released	Minimal

	more water can be released in the lean season		
8.Shift of water intake	Shift of the intake beyond the extent of salinity intrusion. However, even at Panskura, water is too saline	Same as option (3)	Same as option (3)
9.Service level compliance reduced, with user notifications	Information to GPs and to consumers about non-compliance timing	Additional service offices in GP, possible free water	Lump USD 1 mill. (INR 2,100 cr.)

A graphical presentation of the rough cost estimates is presented below. From a cost perspective, construction of a barrage to prevent salinity intrusion is the least attractive although it may be the most robust and long-term sustainable solution. The environmental impact may however be significant. The second most expensive solution is desalination. The cost may, however, be overestimated as it is based on a simple comparison with a newly completed desalination plan in Chennai which produces drinking water from Seawater having the highest level of salinity, whereas in this case, raw water would be brackish water which a much lower salinity. The costs of buffer storage, transmission lines and groundwater mixing may be underestimated as the costs of land acquisition have not been considered. Nevertheless, the analysis show that "smart" water management is by far the cheapest solution although it may not solve the problem completely.

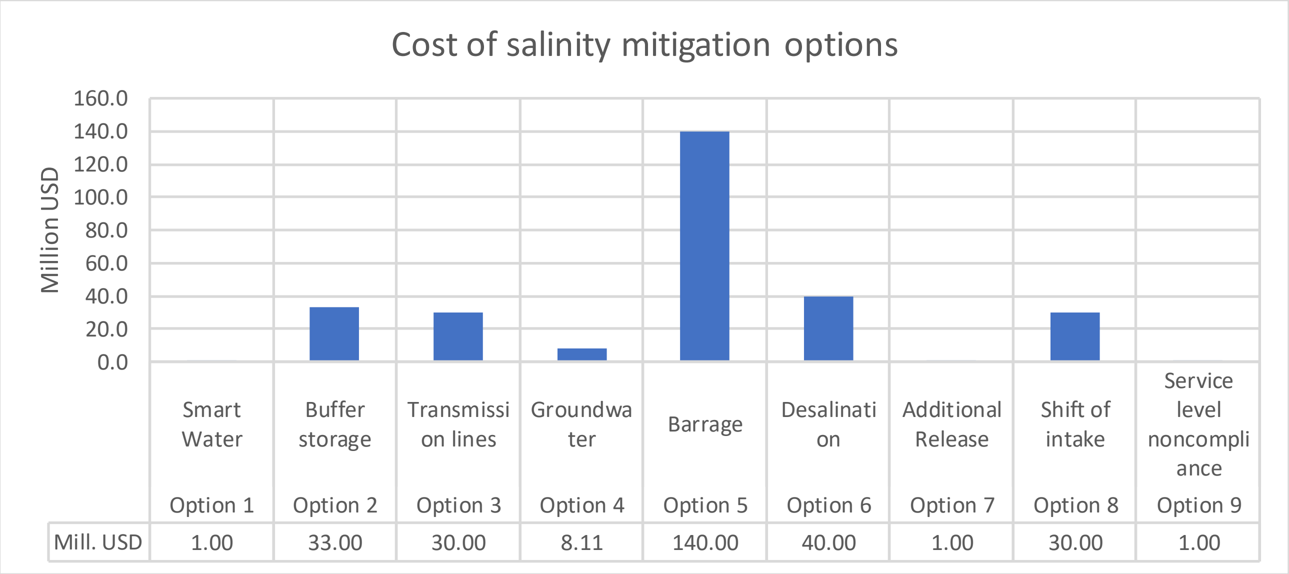


Figure 5-14 Cost estimates of solution options

6 Recommendations

An overview of options is provided in Table 7 below. Based on the cost analysis a quick cost screening is done by indicating the relative cost using a scale from 1 (lowest) to 3 (highest) see below. More accurate cost estimates should be provided in detailed pre-feasibility or preliminary project reports.

The preliminary cost screening indicates that option 1 (Smart Water close monitoring, modelling and management) as well as option 7 (Notification of service levels to end-consumers) are the least costly.

An assessment is provided in the table whether the considered option can be embedded into the existing scope as described in the tender material or whether the scope needs to be extended. Option 1 and 7 will not change the scope. As mentioned in Chapter 1, the tender conditions specify that the Contractor shall be responsible to incorporate climate resilience measures. It can therefore be argued that option (2) and (4) are to some extend covered by that clause. The other options are probably not, although the formulation is weak and therefore negotiable.

Table 7 Overview of options

Option	**Pro**	**Con**	**Cost: score from 1 (lowest) -3 (highest)**	**Change in existing tender scope**
1.Timing by Smart Water Monitoring	No extra civil works	Will not solve issue completely	1	No
2. Buffer Storage Capacity	Simple robust solution, climate resilient	Environmental impact in estuary	2	Partly
3. Transmission pipeline from upstream	No mixing of fresh water in estuary	Dependency on other state/agency	2	Yes
4. Dilution with Groundwater and other	Well known technology	Climate vulnerable, many wells needed	2	Partly
5. Barrage, underwater weir	Salinity intrusion less or prevented	Environmental impact, added flood risks	3	Yes
6. Desalination	Can be located inside WTP	Challenging in O&M, costly	2	Yes
7. Additional release from upstream	No extra civil works	Unlikely, reservoirs will do	1	No
8.Shift of water intake	Same type of solution	Problem unsolved	2	Partly
9. Service level compliance & time varying water quality	Share risk with consumer with good information	Service level reduced	1	No

Option 1 in combination with option 9 is proposed as a immediate solution and is already considered. Both options make extensive use of data-driven processes which will enable much more accurate management of the water supply scheme. Basically, it will introduce a new type of water scheme operation as the scarce water will be utilised right to the limit, and no water will be wasted.

Many structures, barrages, and other control measures already exist in the area as described in this note, and it may be that simply by better real-time management and utilisation of assets, as well as good documentary data to give PHED a better basis for negotiation with other stakeholders struggling for the same water, may be sufficient to mitigate salinity issues during the dry season. If successful, then this approach in smart water management combining integrated water resource management with water supply and water demand management will be highly innovative and useful all over India with cities close to the sea, as well as Worldwide considering that the majority of the population is living near the sea.

For option (1) to work, option (2) is needed i.e. establishment of more storage capacity. Until more storage capacity is established, option (4) i.e. use of groundwater tube well as a backup to surface water with too high salinity levels can be added. In a second phase of the roll out of Vision 2020 of piped rural water supply by the Government of West Bengal, the temporary solution should be evaluated, and a long-term sustainable solution by establishing larger nature-based storage reservoirs should be considered.

Lastly, an extensive feasibility study of a permanent long-term solution based on one of the other options (3) and (6) can be initiated if and as required considering new technology development and/or other infrastructure development in the coming decades in the area.

7 References

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