Improving our understanding of the aquifer systems in Sundarbans

Report of Pump Priming Project

February 2020

INDIA-UK
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UK Coordination Office

UK Centre for Ecology & Hydrology

Benson Lane

Crowmarsh Gifford, Wallingford

OX10 8BB

UK

Indian Coordination Office

Indian Institute of Tropical Meteorology

Dr. Homi Bhabha Road

Pune-411008,

Maharashtra

India

CITATION

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The India-UK Water Centre promotes cooperation and collaboration between the complementary priorities of NERC-MoES water security research.

भारत-ब्रिटेन जल कें द्र एमओईएस-एनईसीआरसी(यूके) जल सुरक्षा अनुसंधान के पूरक प्राथमिकताओ के बीच सहयोग और सहयोग को बढ़ावा देने के लिए करना है

Front cover image: Sundarbans (Emma Bennett, IUKWC)

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Executive Summary

The Indian Sundarbans, a UNESCO World Heritage site is home to 2.79 million people distributed over approximately 1100 villages, with 62 situated on the fringes of the forest. Majority of the population live in acute poverty with marginal living conditions and depend upon agriculture for its livelihood. Agriculture offers limited livelihood potential in the region due to higher sodic salinity levels in soils accentuated by sea level rise and sea water intrusion along with contamination of unconfined aquifers and agricultural lands. With increased crop demand in the past decade, ground water demand has also risen, as the limited rainfall fails to meet year round fresh water demand in the region. As a result, ground water abstraction has become a regular practice, where over abstraction often leads to severe water crisis during summer season.

In this context this pump priming project was conceptualized jointly with National Institute of Hydrology (NIH), British Geological Survey (BGS) and Rajarhat PRASARI to understand the aquifer system in the Sundarbans, by identifying the practicality of artificial aquifer recharge, and its potential contribution to aquifer sustainability and possible role in year round regional water security.

The key aims of the pilot project were –

i. To generate a conceptualized model of artificial recharge with the community;

ii. Understanding communities fresh water demand/need for agriculture; and

iii. Current problems with ground water abstraction from the fresh water aquifers.

Aquifer storage and recovery (ASR) is found to be a potential way of managing water resources to meet existing freshwater demands for drinking and irrigation purpose. It is the direct injection of surface water supplies such as potable water, reclaimed water (i.e. rainwater), or river water into an aquifer for later recovery and use. It can act as an effective adaptation mechanism to ensure long term water security and combat impacts of climate change in the region.

1. Project Leads

The Pump Priming Project 'Improving our understanding of the aquifer systems in Sundarbans' was convened by the India-UK Water Centre (IUKWC) and led by the Activity Leads:

Dr Gopal Krishan

Indian Activity Lead

National Institute of Hydrology Roorkee

Roorkee

Uttarakhand

247667

India

Email: drgopal.krishan@gmail.com

Dr Purnaba Dasgupta

Indian Activity Co Lead

Rajarhat PRASARI

Jadhavpur

Kolkata

India

Email: purnaba.irdm@gmail.com

Dr Andrew McKenzie

UK Activity Lead

British Geological Survey

Maclean Building

Crowmarsh Gifford

Wallingford

Oxfordshire

OX10 8BB

UK

Email: aam@bgs.ac.uk

The Pump Priming Project took place from June – November 2019.

2. Project Aims

The India-UK Water Centre is based around five key cross-sectoral themes and aims to deliver a portfolio of activities across these themes. This activity focused on the theme: Using new scientific knowledge to help stakeholders set objectives for freshwater management and Improving freshwater monitoring frameworks and data for research and management.

The Indian Sundarbans, a UNESCO World Heritage site is home to 2.79 million people distributed over approximately 1100 villages, with 62 situated on the fringes of the forest. Majority of the population live in acute poverty with marginal living conditions. The findings of a household survey conducted as part of this Non Lending Technical Assistance (NLTA) indicates that out of a 1000 typical group of residents, only about 190 get one meal a day, of which 60 get nutrition deficient meals; while of the 1000, 510 (mostly children) suffer from some form of malnutrition. If it is assumed that the sample came from the "richest" administrative block of the region, 310 out of the 1000 people are still below the poverty line; a sample in the poorest parts of the region would see 650 out of 1000 living below the poverty line (World Bank, 2014). Furthermore, increasing population pressure (48 inhabited islands among 102 total islands of Indian Sundarbans), demand-supply gap in fresh water, unsustainable harvesting of ground water, mixing of wastewater pollutants from urban industrial belts and coastal oil spill from non-regulated water transportation systems and increased agriculture activities, has led to severe degradation and destruction of fresh water reserve of the region, hence, affecting the sustainable livelihood vocations of the local people.

Moreover, climate change resulting in frequent natural disasters (like cyclone Aila in 2009), has created a severe fresh water resource crisis leading to loss of human and animal life, habitat and income, and has forced villagers to migrate away from the region. World Bank reported that 250 of a typical thousand residents would have been living close to an embankment that failed in the wake of Cyclone Aila, and on land on which households, livestock, and human lives were lost. Of these 250, only a dozen would have had access to a cyclone shelter. Flooding and salinity intrusion contribute to lower land fertility and higher health hazards. This difficult land of risk and hardship can be termed the "transition zone" – the area between the peri and semi-urban parts of the Sundarbans on the mainland (the "stable zone") and the Sundarbans Reserve Forest. As a result, Sundarbans residents are forced to choose risky livelihood options like- collecting fish seed/ fry from the rivers and collecting crabs and other NTFPs from the nearby forests, which enhances their physical vulnerability and also heavily impacts biodiversity.

Majority of the population depends on agriculture for its livelihood; while a significant part of the population living on the fringes is dependent on forest resources such as wild honey, riverine fish, fish spawn, crabs and turtles, as their primary livelihood. Agriculture offers limited livelihood potential for communities due to higher sodic salinity levels in soil (up to 16dS during summer). This condition is accentuated by the fact that the Sundarbans is reported to be sinking due to sea level rise of about 12mm (since 2006) every year (Hajra & Ghosh, 2018; Molinari, 2017). The sea level rise also results in increasing the vulnerability of the area to sea water intrusion and contamination of its unconfined aquifers and agricultural lands. In recent times with increased crop demand, ground water demand has also risen as the limited rainfall (1600-2000mm per annum) fails to meet year round fresh water demand in the region. As a result, ground water abstraction has become a regular practice, over abstraction often leads to severe water crisis during summer in the region.

Figure 1 presents the status of ground water level in Indian Sundarbans, which is at 5-6m depth therefore not very far from the base of aquifer. However, the nature of the ground water at such a shallow depth is saline. Moreover, this salinity varies with season, in the summer months it rises to almost double or more than double than that of monsoon. Given the very fragile nature of the ecosystem and the state of surface and ground water resources the current project aimed to:

i. Improve the understanding of the aquifer system in the Sundarbans for identifying the scope for Aquifer Storage and Recovery; injecting fresh water into the saline shallow aquifer system during monsoon months and recovering it for dry season. This approach could possibly avoid risks of aquifer degradation or contamination associated with conventional recharge of the freshwater aquifers; and

ii. Understanding the practicality of artificial aquifer recharge and its potential contribution to aquifer sustainability.

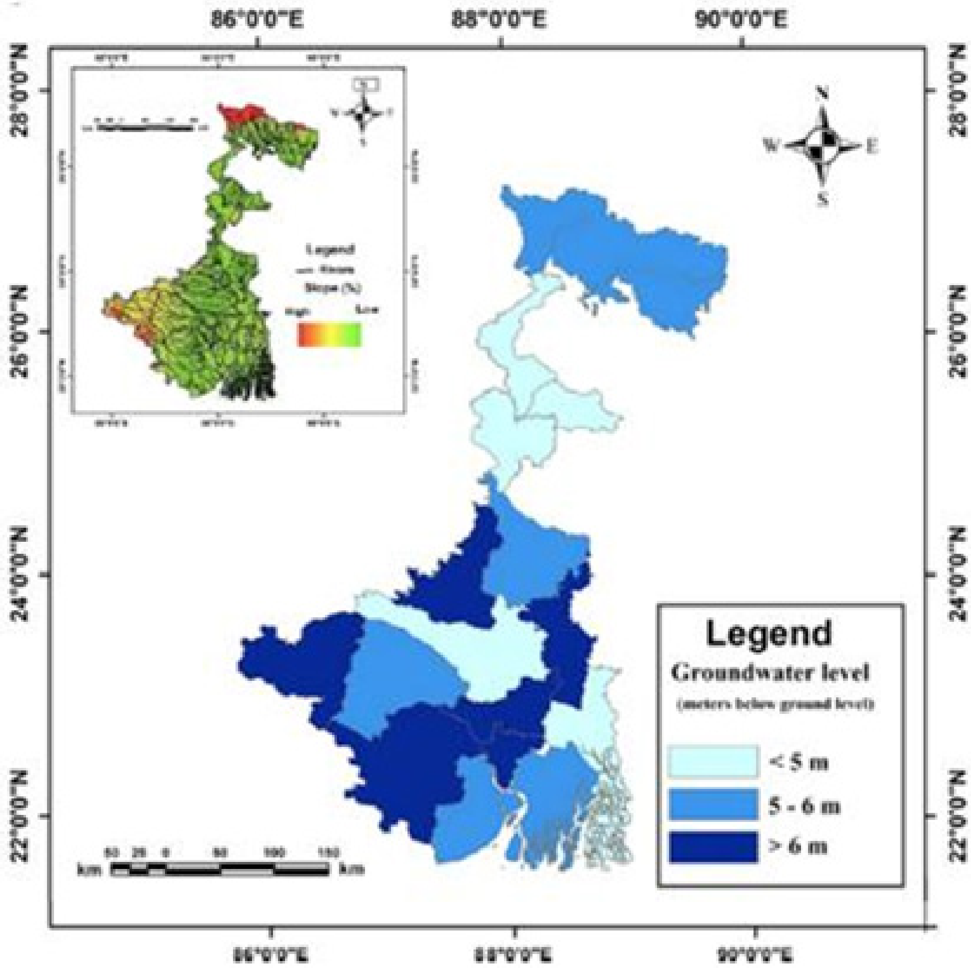

Figure 1: Groundwater level in West Bengal (Chaudhary and Bahera, 2006)

By developing an understanding of the above, the project envisages to work towards improving the livelihood of the people in the region in a sustainable manner and ensuring water security and balance in the ecosystem.

Specific Objectives –

- Develop a conceptual model of the island aquifer systems and collate available evidence on aquifer extent; - that is through - Aquifer Storage and Recovery System
- Collate aquifer property data on the aquifer systems, including data on the shallow saline aquifers; - Through primary data collection
- Review the potential and cost/benefits of aquifer recharge and aquifer storage and recovery; - Economic aspects of the ground water recharge (cost benefit ration).

Figure 2 Participatory Ground Water Management; Picture Credit: PRASARI

3. Project Team

The Pump Priming team was made up of staff listed in Table 1.

Table 1. List of Project Team Members

	Name	Institution
		INDIA
1	Dr Gopal Krishan	National Institute of Hydrology, Roorkee
2	Dr Purnabha Dasgupta	Rajarhat Prasari
3	Mr Saikat Pal	Rajarhat Prasari
4	Mr Gouranga Banerjee	Rajarhat Prasari
5	Mr Goutam Banerjee	Rajarhat Prasari - Research Assistant
6	Ms Sutapa De	Rajarhat Prasari - Research Assistant
7	Mr Dulal Mondal	Rajarhat Prasari - Research Assistant
8	Mr Uday Mondal	Rajarhat Prasari - Parahydrogeologists
9	Mr Tilak Mondal	Rajarhat Prasari - Parahydrogeologists
10	Ms. Kalpana Howdy	Rajarhat Prasari - Parahydrogeologists
11	Ms Maharani Gharami	Rajarhat Prasari - Parahydrogeologists
12	Ms Sujata Mondal	Rajarhat Prasari - Parahydrogeologists
		UK
13	Dr Andrew McKenzie	British Geological survey, Wallingford

4. Project Structure

The project envisaged to explore the feasibility of natural resource based asset creation and its integration in the environmentally challenged deltaic riverbank and coastal saline agroecosystem of the Indian Sundarbans, for improving the water security of resource dependent livelihood vocations of men, women and youth in the area (comprising of 19 blocks from 2 districts). It also aimed to gain a perspective of widespread unsustainable practices in the area related to agriculture, horticulture, livestock, commercial aquatic and forest dependency. The project aimed to understand the viability of implementing localised community-based models for co-creating environment friendly livelihoods, preserving water resources through artificial recharge and using improved social mechanism for ground water usage while preventing enhanced migration, water salinity and associated quality degradation of other natural resources.

To achieve its aims, the project proposed to build community driven data collection platform in developing climate resilient coping mechanisms to tackle severe water crisis and for grounded planning at the gram samsad level and or, convergence with MGNREGS(Mahatma Gandhi National Rural Employment Guarantee Schemes). In additon to these, practices for establishing and conserving of ground water management, rain water harvesting, land shaping techniques, artificial ground water recharge, co-creation and sharing in multi-stakeholder platform and establishment of sustainable community driven water sharing models for sustainable livelihood promotion were also explored.

The project was structured to:

a. Develop community platforms for crop-water planning;

b. Enable locals to facilitate alternative water conservation methods;

c. Identify sustainable innovative measures and technologies for aquifer storage and recovery;

d. Explore feasibility of implementing activities through community platforms considering integration into appropriate eco-entrepreneurship models;

e. Explore the options to diversify, enhance and secure sustainable livelihood options through water resource based asset creation, livelihood integration and generating appropriate business models; and

f. Explore feasibility of measures for monitoring of water sharing in the community to avoid water related conflicts at a local and regional level.

The major activities undertaken in the project were address the above were ideas–

- Socio-hydrological survey – using stratified sampling based on the Central Ground Water Board (CGWB) well data;
- Identification of water crisis in agriculture through field survey & result triangulation through community workshops;
- Collection of rainfall data, pump testing, soil-lithology data from the field;
- Water level monitoring (pre and post monsoon) and validating with the community;
- Collection of water sample for isotope test; and
- Developing simulated ASR model feeding the observation data.

The project included exploring the feasibility of establishing practices of ground water management, rain water harvesting, land shaping techniques, artificial ground water recharge, co-creation and sharing in multi-stakeholder platform and establishment of sustainable community driven water sharing models for sustainable livelihood promotion.

4.1. Data collection methods

The current section details on the methodology followed for data collection.

A. Socio-hydrological survey – using stratified sampling based on the CGWB well data – A socio-hydrological survey was organized keeping in view the seasonal variability in fresh water quality and quantum in the project area, i.e., Gosaba and Sandeshkhali II of Indian Sundarbans. Total 264HHs were covered under this survey where both livelihood and ground water usage were collected to address the hypothesis that there was no ground water related conflict. Field level data was also collected from 264 water sources in the two community development blocks of Indian Sundarbans. The main focus of the field survey was on groundwater dependacy, hydrogeological parameters, water quality tests, number of groundwater structures etc.

B. Identification of Water crisis in agriculture through field survey & result triangulation through community workshops. Water crisis data was collected through Focus Group Discussion and community workshops to identify the extent of such crisis, spatio-temporal ranking based on gravity of the problem, seasonality of such crisis, participatory actions to address the problems, etc.

C. Collection of rainfall data, pump testing, soil-lithology data from the field. Manual rain gauge were used to collect the rainfall data; for soil lithology, identification of the new deep tube-well constructing sites; direct soil sample collection and triangulation in the community workshops was undertaken along with pump testing in the new sites.

D. Water level monitoring (pre and post monsoon) and validating with the community. Water level was monitored using tapes. Para-hydrogeologists monitored the water level twice every month in the pre and post monsoon months.

E. Collection of water sample for isotope test. In this case autoclaved water bottles were provided to Para-hydrogeologists who collected monthly water samples on the same date and location over a period of four months.

F. Developing simulated ASR model feeding the observation data. With the help of pump testing data, transmissivity, storativity, soil lithology, etc. were calculated and based on this data BGS is currently preparing a simulated ASR model for Indian Sundarbans.

Participatory activities and data collection flow chart

Participatory Aquifer mapping	•Training para-hydrogeoplogists •Creating space for the community and preparing conceptual models of participatory aquifers
Crop-Water Management plan	•Preparing land use map and water flow map with the community for feeding in to crop-water management plan for the localility / patches
Water Use Management Plan	•Participatory water use management plan will be prepared and followed for each island based on the demand and supply of fresh water in the said island and on the preliminary data collected
Lithology data collection	•Soil lithology data collection using para hygrogeologists and trinagulation with the community
Enabling local community	•Enabling local and cluster level platforms to emerge as community leaders championing the conservation and protection of ground water with a view to diversify sustainable livelihoods •Enabling local parahydrogeologists to facilitate the participatory data collection process
Technical Support	•The scope ofassisting local communities to devise appropriate techniques to conserve ground water was facilitated through this project
Multi-stakeholder platform	•Scope for establishing multi-stakeholder forums, which bring together the representatives of village institutions, civil society groups, academia and government functionaries to enable better policy coherence and action planning was explored
Monitroing and overall managemnt	•Concurrent monitoring and tracking of data was done on regular basis

4.2. Organization of workshops

3 exploratory workshops, social and scientific in nature were organized as a part of the project to gain an insight of stakeholder perspectives and state of current science in groundwater management.

Participatory Groundwater Managment (PGWM) workshop

1 PGWM workshop each at Sandehskhali II and Gosaba blocks was organized by the project team to develop understanding of:

- The Ground water table;
- The problems associated with drinking and irrigation water in the Block;
- The issues faced by the local people in general, to get access and use of fresh water for various purposes like- agriculture, drinking and household chores;
- Training of the volunteers to collect water samples for isotope test.

These workshops proved to be very useful in getting first hand insight on groundwater levels, seasonal variations and salinity ingress in the study area and it helped the participants build their confidence in the possibility of ground water recharge and replenishing of their ground water aquifer. The workshops also helped initiate awareness of fresh water conservation for efficient use in the near future or in the lean period (for details on these workshops refer Annex A).

Technical workshop

1 technical workshop on Groundwater Recharge, reduction in soil salinity and way forward for Indian Sundarbans was organized at ICAR-CSSRI, Canning Town with the objectives to get the baseline information; data dissemination for developing a conceptual model of the island aquifer systems and collate available evidence on aquifer extent; methodology to collate aquifer property data on the aquifer systems, including data on the shallow saline aquifers. The key points issues associated with the region discussed at the workshop were:

Soil salinity: Entire area is affected by soil salinity; during kharif season salinity is less due to leaching (ponding of water leads to leaching), but high in rabi season (mainly from January onwards) when drying starts and patches of salt deposits can be seen.

Acid saline soils: In some areas soils with high acid sulphate ratio resulting in high levels of acidity with salinity are found. Acid sulphate soils are found in sub surface layers and are exposed after digging operations; these soils severely affect crops and hamper fish growth resulting in high fish mortality rates in fresh water bodies.

Water availability: Availability of water for irrigation and good quality water for drinking is a major issue in the region due to the depletion in ground and surface fresh water levels as well as deterioration in quality.

Climate Change threats: Mainly increase in frequency and intensity of extreme events like cyclones and changing rainfall distribution.

(for details on these workshops refer Annex B).

Final/technical/data dissemination workshop

In this workshop researchers, academicians and policy makers associated with Indian Sundarbans were invited to share their work experiences and vision for improvement of this region. The panel discussions were also held on the livelihood issues, soil and water conditions of Sundarbans and outcomes of this workshop are very much useful in co - development of innovative techniques for management of soil and water of the region and to improve the livelihood of the local inhabitants. The results obtained form this project were also presented and appreciated

For details on workshop discussions and agenda refer Annex C.

5. Activity results and conclusions

To work towards livelihood sustainability and improving water security in the region, ensuring sustainable and secure supply of fresh water for drinking and agriculture purposes is thought to be key. The current project first aimed to understand the hydrology and sub-surface aquifer system of the region to contribute towards exploring the potential of rain water harvesting in the region. This section provides details on the results of research work conducted over the region.

5.1. Socio-hydrogeology of the Study area (results on survey conducted)

Korakati Gram Panchayat comprising of three revenue villages of Korakati, Tushkhali and Duchnikhali are a part of the Sandeshkhali II block of 24 North Parganas district of West Bengal. The villages have been selected under the BRLF programme for convergence of various government schemes for beneficiaries comprising of tribal people from the village. These villages were also selected for the Participatory Groundwater Management under this project. The project team aimed to understand issues pertaining to groundwater and water in general, study local hydrogeology, monitor rainfall and selected tube-wells from the area to understand groundwater movement, map aquifers and conduct water quality analysis. The objective was to develop an informed understanding about groundwater dependency and associated issues in the village and come up with a management plan aimed at equitable distribution of this common pool resource and ensuring sustainability of the same.

A household and field scale survey was conducted in villages of these blocks to identify options sweet/fresh water currently being utilised in the lean period and to collect primary data on water sources in the region.

Water for drinking and domestic uses

The main sources of water for various uses in the region are found to be mainly;

1. Pumping of ground water using submersible pumps
2. Import water from outside using pipes
3. Desalinisation of the saline water using appropriate equipment.

These methods were identified to be expensive, unsustainable and vulnerable to impacts of climate change in nature. Given the above options, there is an overwhelming dependency on groundwater in the area for drinking and domestic use. Locals estimated that there are approximately 1500- 1800 privately owned tube-wells in the Gram Panchayat and about 180 government owned tube-wells. No dug-wells were however observed or reported in the region; one of the reasons shared by the people was that the water at shallow depths is saline and hence not potable (table 2 highlights the dependency of rural population on ground water).

Table 2: Dependency on ground water

Revenue village	GW Dependence	GW occurrence Depth levels	GW related issues
Duchnikhali	Irrigation + Drinking water	1000 feet, 600 feet, 400 feet	Drying up of tube wells
Tushkhali	Irrigation + drinking water	600 feet, 400 feet	River embankment, GW competition
Korakati	Drinking water	400 feet	No issues reported

A number of farm ponds were also observed throughout the Gram Panchayat area; although saline, they were found to be used for other domestic purposes like washing, etc. The water from tube-wells was found to be largely untreated before drinking and was perceived as good quality water by users. In terms of sanitation, only 30 percent of households in the Gram Panchayat had access to toilets and many of them were irregularly used or were defunct. In one of the villages (Mauja, Korakati), the Swajaldhara scheme was operational wherein the govt. has provided a tubewell of 1100 feet depth which is used to supply domestic water to the households. The exact number of households benefited under this scheme is not available.

Water for agriculture

The dependency on tube-wells for drinking water is being challenged by increased sourcing of tube-wells for irrigation purposes. The ground water quality of the area was observed to be quiet poor, wherein the salinity and total dissolved solids are reported to be higher than permissible limit. Iron concentration was also found to be greater than permissible limits in various hand pumps and tubewells.

Paddy is the only crop taken in the area, cropped twice a year, in monsoon and winter. The winter paddy requires extensive irrigation which is sourced through these tube-wells (fitted with 3 to 5 Hp pumps which are centrifugal and non-submersible). There are an estimated 500 tube-wells currently being used for irrigation purposes (information received on the basis of local discussions). Currently the area under winter rice cultivation is limited but more and more people are adopting shallow tube-wells to get an irrigated winter crop. Out of the three revenue villages, it was reported that the Tushkhali Mauja has the highest number of irrigation structures. Perceived problems of groundwater in the region is its observed depletion in the months of February - March annually over the past few years. People perceive increase in area under winter cultivation, increasing number of tubewells and decrease in rainfall as reasons for depleting groundwater in the area. Figure 3 highlights the growth in quantity of irrigation tube wells as derived from rural participatory sessions and from 1663 tube wells surveyed in this study.

The graph depicts an increasing trend in use of irrigation tube-wells in the Gram Panchayat area for rabi crops. It can be observed that about 175 tube-wells were constructed for this purpose from 1960 to 2010 and the same number of tube-wells have been constructed in the current decade upto 2016. This rate of development is alarming and poses a threat to the local water security since both the uses (Drinking and Irrigation) predominantly source water from a single aquifer system i.e. the 340-420 feet aquifer. The members of the community reported hand-pumps from this depth going dry during summer as shown in the figure 4.

Village Water & Sanitation Committees (VWSCs) or Pani Samiti to plan, design, implement and manage their own drinking water supply programme along with collating other basic necessities like village cleanliness and sanitation thereby focusing on better health and hygiene of the rural communities.

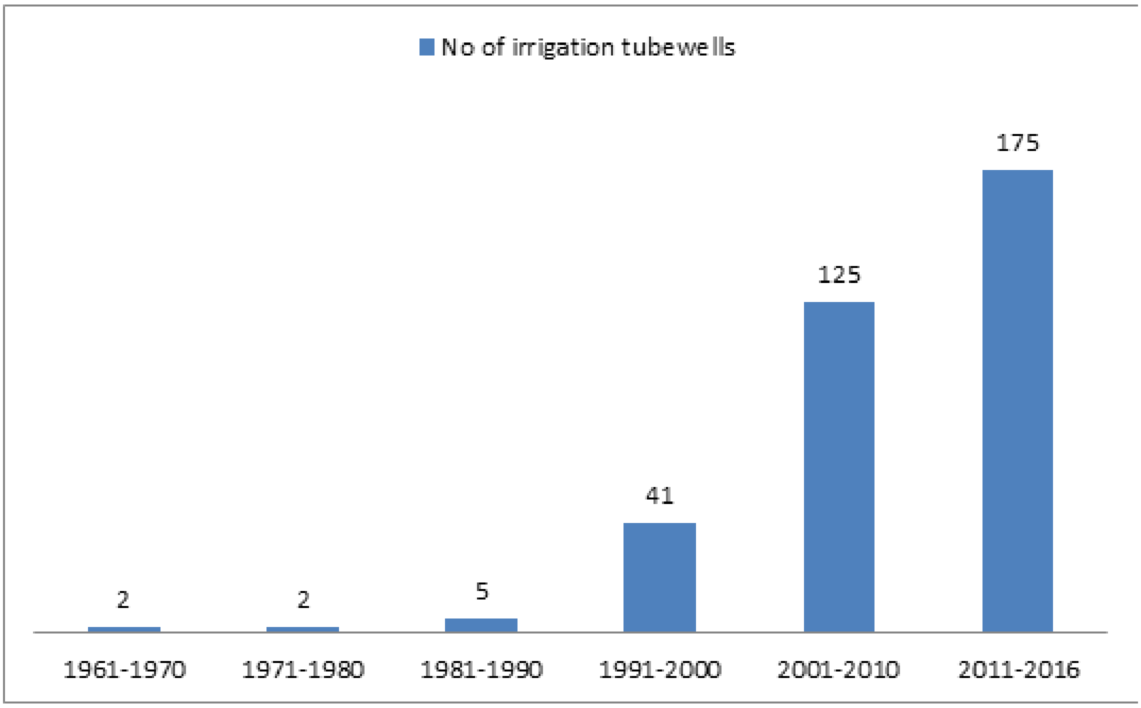

Figure 3: Participatory mapping of Irrigation Tubewells

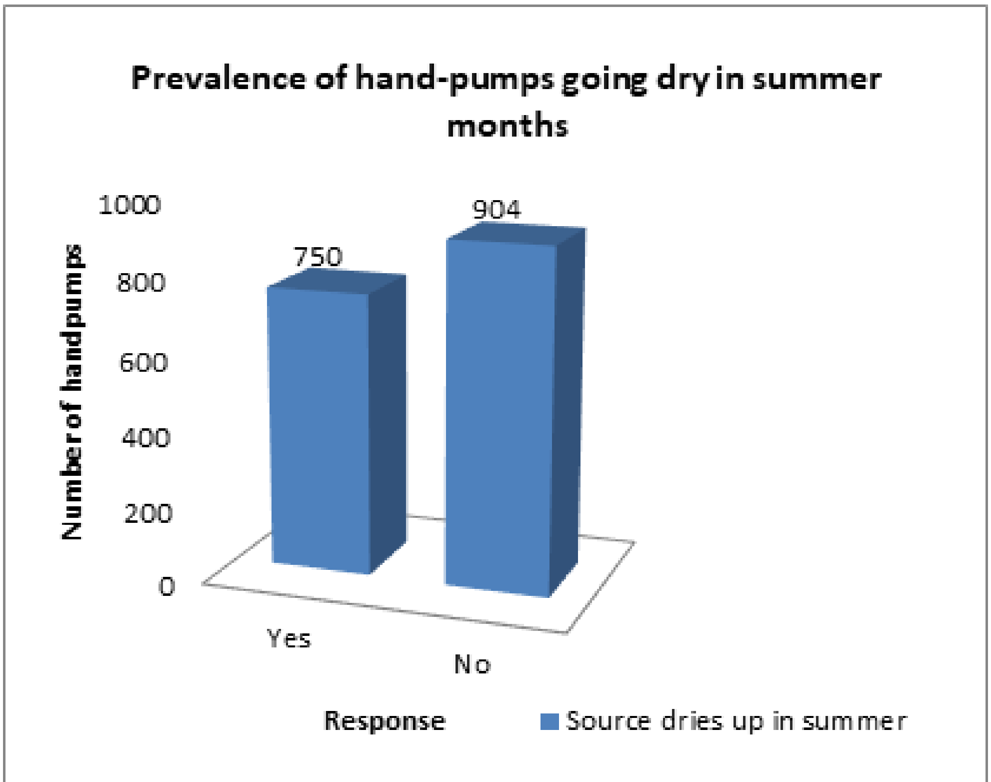

Figure 4: Participatory mapping of hand pumps gone dry in the summer months

Detailed interviews with some farmers were conducted regarding water use for irrigation. It was reported that the irrigation tube-wells are being used for a period of 3 months from January to March for cultivation of winter crop in the area. The tube-wells are pumped for 10 hours daily, which amounts to about an alarming 1000 hours of pumping from a single tube-well.

Groundwater balance

Looking at development of groundwater in Korakati Gram panchayat (Figure 5) it is evident that there has been tremendous development of groundwater sources in the last decade and a half. This development has been reported to be mostly privately sourced; majority of these wells being increasingly used for irrigation purposes

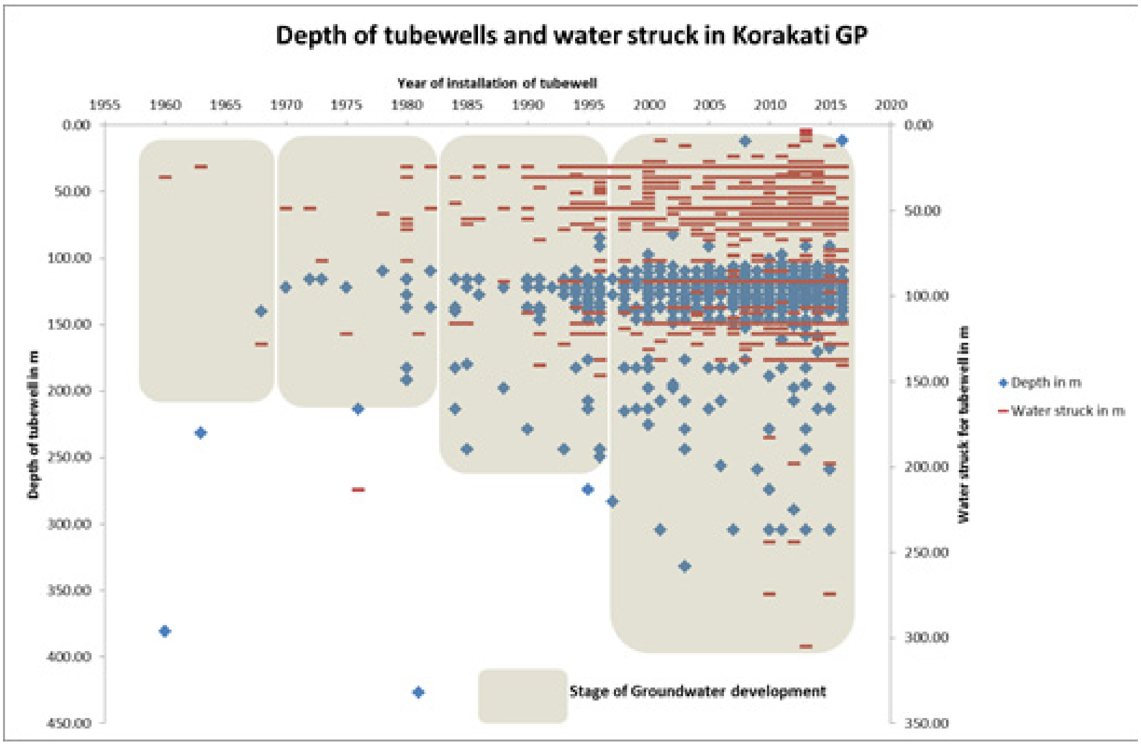

Figure 5: Year wise progress of the depth of tubewells in the study area

The amount of tube wells dug for irrigation has created immense pressure on the ground water aquifer in the region. It is critical to develop an understanding of ground water balance and aquifer characteristics of the regions to suggest measures for improving sustainability of the resource. An understanding of aquifers requires a quantitative assessment of both the inputs (recharge) and the outputs (discharge) from the aquifer (Macdonald et al., 1995). Since assessment of groundwater balance of a confined aquifer is not possible through water level fluctuation method; other factors like aquifer storage and total groundwater abstraction need to be taken into consideration. Table 3 summarises the effort to derive groundwater balance in the region; aquifer storage was calculated through aquifer thickness and storativity of the aquifer. The value of storativity of the aquifer was taken from pumping test carried out during the project. A huge gap is observed between potential aquifer storage and probable aquifer storage; this gap could be potentially fulfilled through implementing frequent groundwater augmenting programs.

Table 3: Groundwater balance

Order	Particular	Year
A	Year of calculation	2019-20
B	Potential aquifer storage	3465 mm
C	Actual aquifer storage	2100 mm
D	Total groundwater abstraction through pumping	40825920 Cum

Hydrogeology of the area

Developing an understanding of the hydrogeology of a region is useful to identify the nature of hydrological flows and lithological characteristics that affect ground water storage and recharge. Discussions with the para-hydrogeologists were very useful in getting a primary picture of the hydrogeology of the area. Figure 6 highlights that the basic nature of soil in mainly alluvial in the region; the figure also helps identify drainage pattern and ground water sources in and around villages in the region.

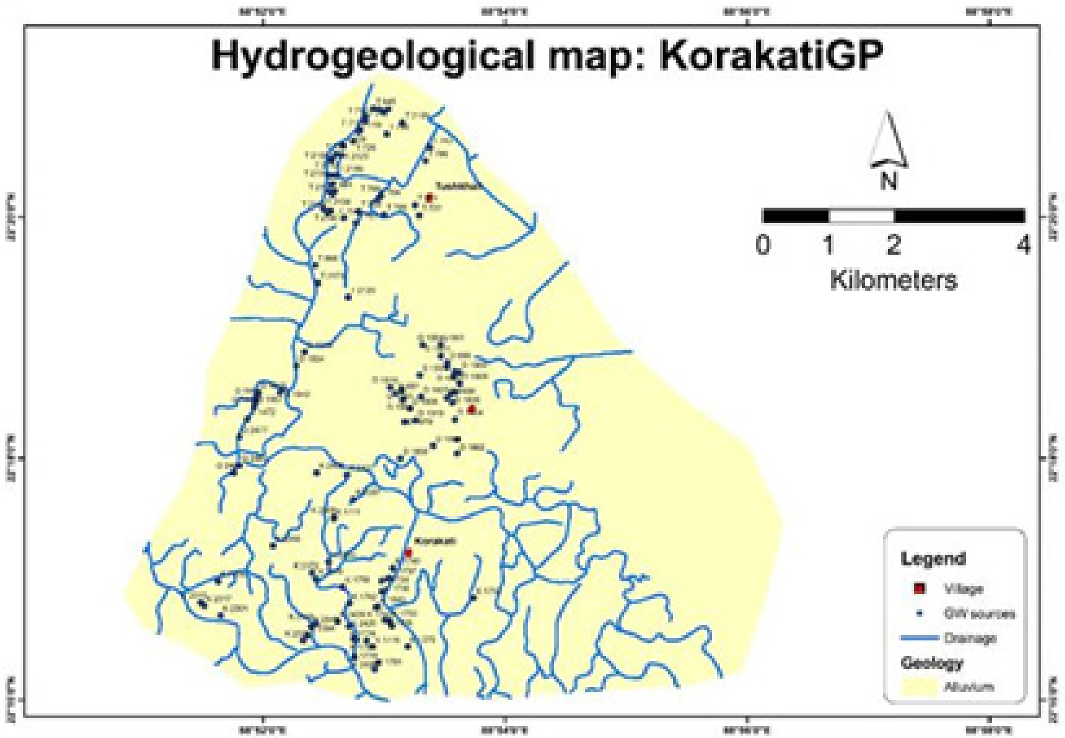

Figure 6: Hydrogeological map of Korakati

With further inputs from local stakeholders and from discussions with the para-hydrogeologists a conceptual aquifer model was developed for the region to understand the aquifer profile and water storage (Figure 7).

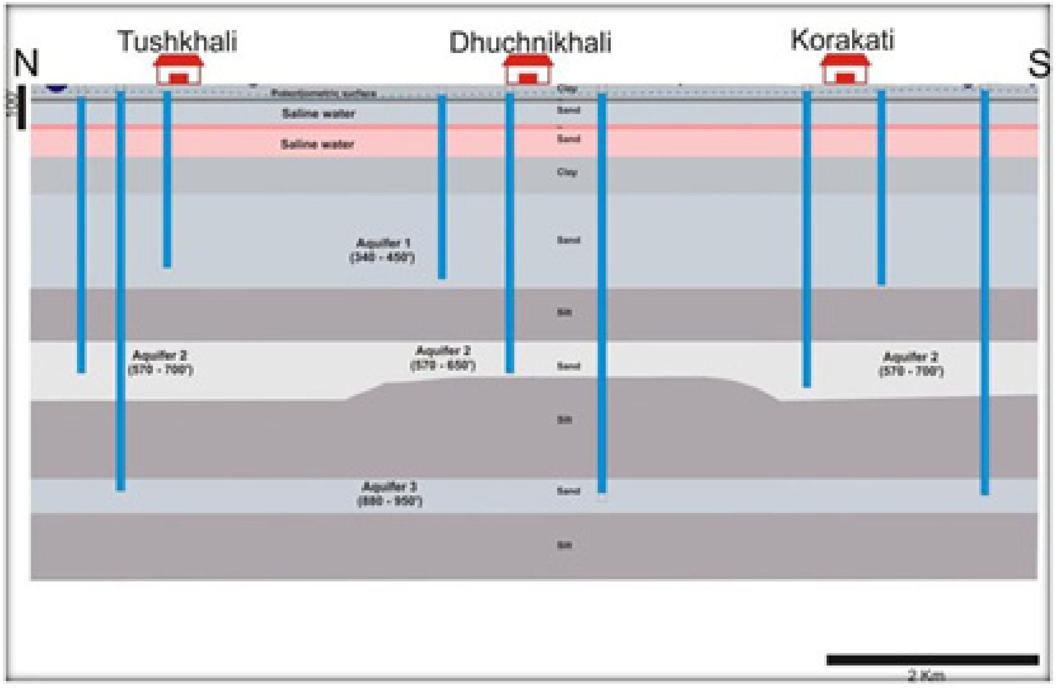

Figure 6: Conceptual Models of Aquifers in the study area

It was observed that various aquifers are present from top to bottom and are based on presence of percentage of sands in this area; the upper aquifers however are reported be highly saline in nature. Three major aquifers have been mapped in the area which are confined in nature and provide fresh water. Aquifer1 is found to be at a depth of 341 to 450 feet; aquifer 2 at 571 to 650 feet in Dhuchnikhali and 571 to 700 feet in Tushkhali & Korakati; while aquifer 3 is placed between 881 to 950 feet deep from mean sea level. All the three aquifers represent potentiometric water level ranging from 3 to 7m below mean sea level (msl). Maximum numbers of hand pumps and irrigation tube wells are reported to tap aquifer 1 while some government installed hand pumps are reported to tap deeper aquifers.

Water quality data and its quantitative assessment

Ensuring optimal water quality is very critical when delineating aquifers for domestic use, especially for drinking. Different aquifers show different water quality; water sampling for assessing its quality was undertaken in the aquifers of the study area to identify its suitability for consumption and for artificial recharge along with assessing the diversity in quality across aquifers.

In situ water quality analysis was done for basic parameters like TDS, pH, and salinity. Parameters like salinity, total dissolved solids (TDS) and electrical conductivity were found to be slightly over the permissible limit; whereas pH and fluoride were under the permissible limit. Traditional methods for testing the iron content in water were experimented with on site (like using guava leaves in the field). It was observed that older hand-pumps have high iron content, due to rusting of iron pipes; the results were cross referenced through laboratory testing of water.

Twelve representative samples were sent to the regional laboratory for detailed analysis of physio-chemical parameters including iron, magnesium, calcium, arsenic, hardness, TDS, electrical conductivity and pH. Piper and Wilcox diagrams were plotted to understand the nature of fresh, mineralised and saline water along with sodium absorption ratio (SAR) and salinity of water respectively (Figures 7 and 8). Most of the tested water samples were found to represent mineralised water, whereas few samples fell in between fresh and mineralised water zones.

Wilcox diagram (Figure 8) shows, all of the water sources fall in medium salinity and low sodium absorption ratio (SAR).

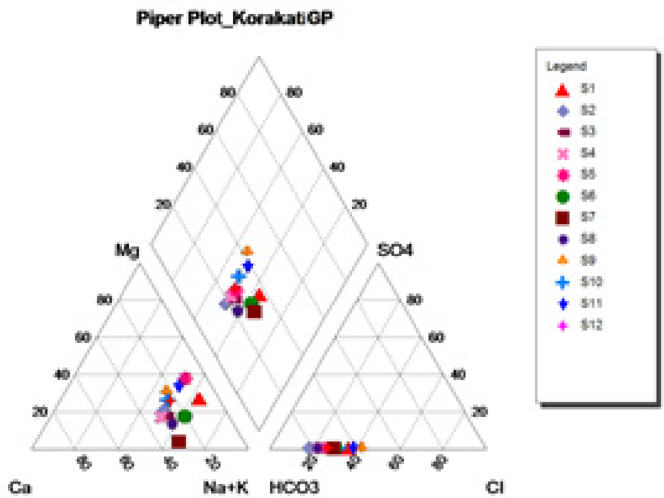

Figure 7: Piper Plot

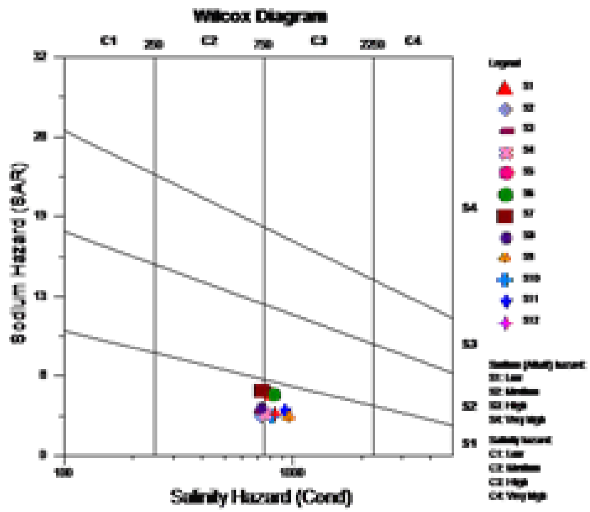

Figure 8: Piper Plot

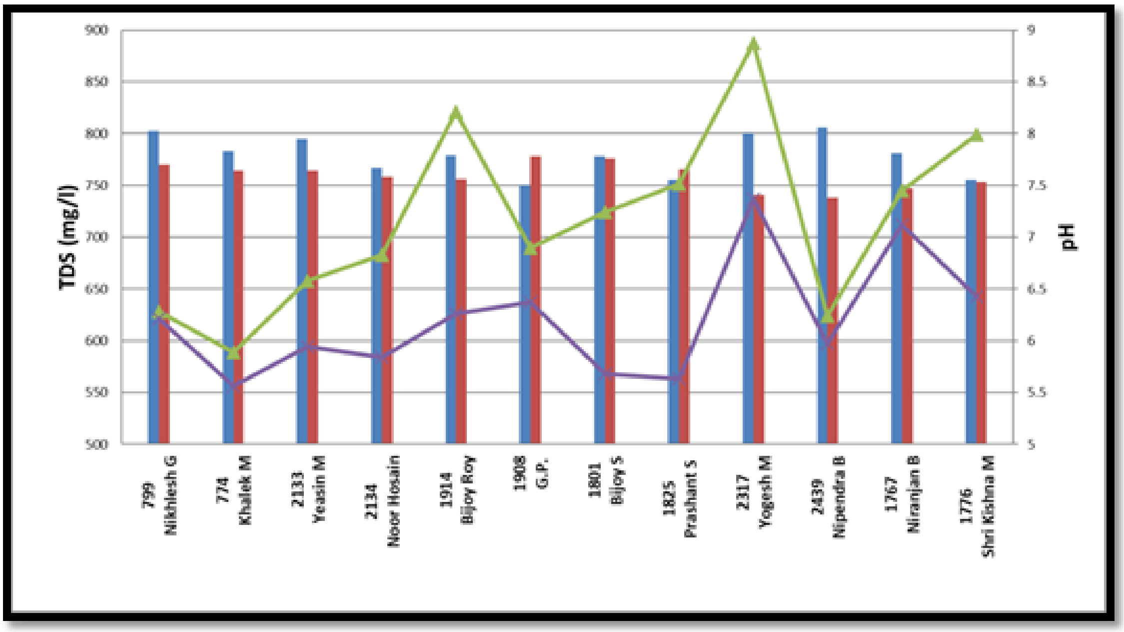

Figure 9: Highlights the scenario of TDS and pH in the water samples.

As per the assessment of the area carried out under this project sustainable and secure supply of good quality fresh water for drinking and agriculture purposes throughout the year is a major concern amongst the populace. The issue of availability of good quality water is drastically affected by the disaster prone, coastal and saline agro-ecological nature of the region. The following section explores the feasibility of implementing an Aquifer storage and recovery (ASR) system in the study area to address its water security issues.

5.2. Aquifer Storage and Recovery System

Aquifer storage and recovery (ASR) is a way of managing water resources to meet existing and future freshwater demands. It is the process of direct injection of surface water supplies such as potable water, reclaimed water (i.e. rainwater), or river water into an aquifer for later recovery and use. In the case of Sundarbans, use of reclaimed water and its storage in the saline aquifers seems most relevant given the climatic and hydrogeological nature of the region. This technique is useful as an alternative to building surface storage for the dry season along with repairing 'damage' to an aquifer from over pumping or changes in land use.

The rainwater sourced ASR techniques is ideal to help to retain the rainwater within a given area and maintain its quality for consumption. The stored water can be extracted from wells in the lean season and used mainly for irrigation. The basic process of ASR is highlighted in figure 15.

The key constraints behind this model are summarised in Box 1.

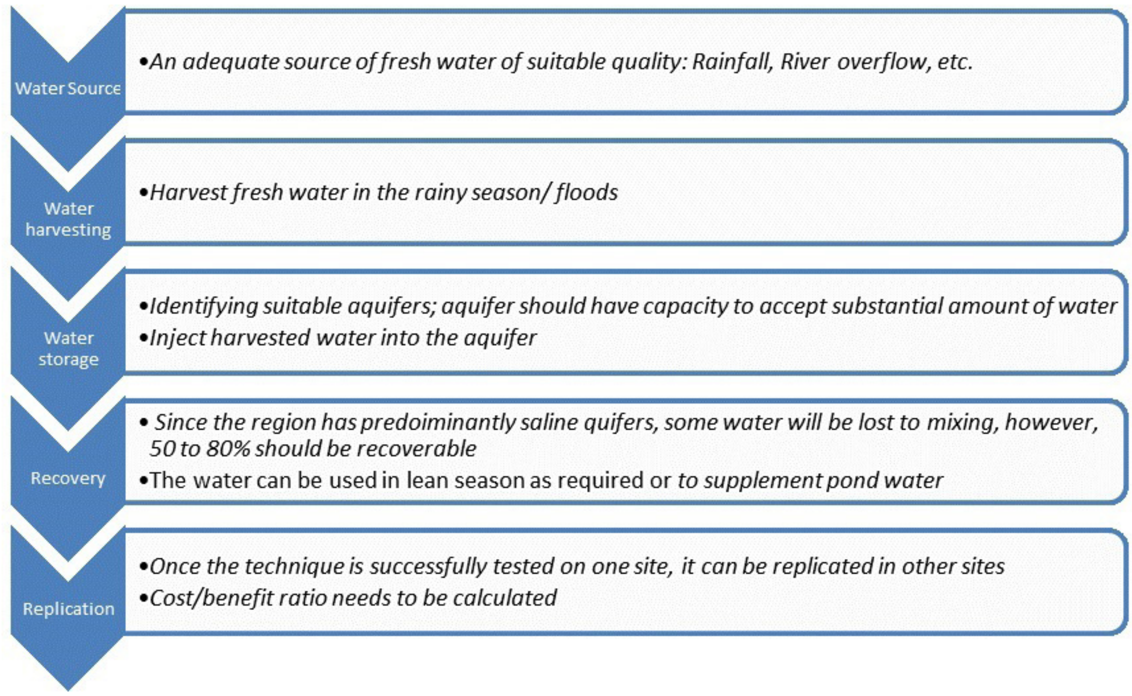

Figure 10: Framework for artificial recharge of aquifers.

BOX 1: LEY CONSTRAINTS IN CONSIDERATION OF ASR

Key constraints identified are as:

1. Head constraint: This can be explained through Cooper Jacob expression used to calculate groundwater mounding over a 100 day injection period

$$h_w - h_o = \frac{2.3Q_D}{4\pi T} \log \frac{2.25Tt}{r^2S}$$

Where, h = Head; Q = discharge; T= Transmissivity; S = Storage

2. Water Availability

- Rainfall during typical monsoon months > 1000 mm so fresh water availability not a constraint. Typical ponds could receive up to 2400 m3 of water per season,
- If we use 50% of available recharge, 1200 m3 of water
- For continuous injection that’s 0.14 l/sec over 100 days
- We will recover 600 m3 of water or > 3 times water available from our pond
- If we had more water, At 1 l/sec over 100 days, we can recharge 8500 m3

As per assessment undertaken in this project considering the region and its people, there are three main aspects that need to be deeply understood and considered in connection with adopting the framework as represented in Figure 10. These are:

Understanding fresh water resource and aquifer characteristics

a. Quantitative assessment

A finer scale of understanding of aquifers requires a quantitative assessment of both water inputs (recharge) and outputs (discharge) in the region. Since assessment of groundwater balance of confined aquifer is not possible through water level fluctuation method; factors like aquifer storage and total groundwater abstraction as used in this study to calculate groundwater balance need to be determined at a wider scale. In this study, aquifer storage was calculated through aquifer thickness and storability of the aquifer. A huge gap between potential aquifer storage and probable aquifer storage was observed; this can be fulfilled through more groundwater augmenting and quantification programs.

b. Water Quality related issues (related to aquifers)

There should be periodic assessment of water quality parameters such as: pH, TDS, turbidity, iron, arsenic etc. Arsenic in groundwater has been reported in this basin by many researchers and there is a need to identify possible long term measures for its treatment.

c. Aquifer resistivity to drought and cyclone

Sundarbans area is prone to frequent drought and cyclones. In ASR, deeper aquifers are targeted as opposed to shallow aquifers which increase resistance to drought and cyclones and portray a lesser possibility of saline water intrusion.

ASR system: Implementation, maintenance and performance

a. Cost of artificial recharge

The overall cost of developing an ASR system maybe high initially but the same is significantly low from long term perspective and from taking into considerations costs for importing water. If we calculate approximate costs for recharge, approximate costs total to a little over 1,00,000/- INR:

- Drilling a borewell and casing to 40/50 metres, INR 40,000
- Use the solar pump and tank system introduced for the drip irrigation system
- Pump and tank circa INR 15,000
- Area ‘irrigated’ increases from 750 m2 to 3000 m2
- ‘Additional expenses’ of Rs 3000 to 27,000
- Key sensitivity is crop profitability

b. Technology transfer: mechanism, management and maintenance

This system has been tested under laboratory conditions at a small scale, so there is a need to test it under field conditions on a larger scale. The key factor affecting the extrapolation if this technology is mainly the lithology (small volume ‘fresh water bubble’ will have high surface area to volume ration in a thick aquifer).

c. Quality control

Artificial recharge requires filtration system to be added to aquifer; this may require additional costs

d. Aquifer heterogeneity and fluid-rock interactions can greatly affect ASR system performance.

Aquifer heterogeneity and fluid-rock interactions can greatly affect ASR system performance. The metaphoric "ASR bubble" has been burst with the realization that ASR systems are more physically and chemically complex than the general conceptualization. To counteract this, in this study we have gathered as much lithological data as possible to generate first hand data and validate the same through participatory aquifer storage and recovery system. The same will be useful to run solute-transport ground water modelling required to predict how stored water will migrate over time, given different conditions and how saline aquifer properties will affect the quality of stored water. It has been well-demonstrated, by model generated using Jupyter Notebook (python as the backend programming language), that ASR systems can provide very large volumes of storage at a lesser cost than other options in Indian Sundarbans. The challenges moving forward are to field test the success of ASR systems, optimize system performance, and set expectations appropriately.

Social awareness and capacity development requirements

Ensuring participation from the society is very crucial for successful understanding of the ground water dynamics and planning activities for improved water use efficiency and conservation. This section highlights the key facets that need to be considered in this context.

a. Community data sharing platform

A participatory data repository along with community data sharing platform needs to be created with water users to regulate and maximize optimal use of fresh water. Simulated model on artificial recharge (ASR) in this regard will be very useful to generate alternative water source option in the Indian Sundarbans.

b. Awareness on resource conservation

Facilitating resource availability needs to be complimented with generating awareness amongst masses on resource conservation to ensure conservation of water in aquifers and avoid over exploitation. A social mechanism on resource sharing also needs to be developed and propagated in the region

c. Knowledge sharing and Skill development

Stakeholders, including the society need to be involved since inception of such a water conservation measure. This will not only facilitate adhoc participation but also generate awareness on using water in an efficient manner amongst the users.

Frequent training and skill building amongst the society to monitor, manage and maintain the artificial recharge system, data platform and water sharing platform would be key to ensure smooth and long term functioning of the system for a sustainable future.

Organization of frequent participatory groundwater management (PGWM) workshops and mass awareness programmes is tough to be quite useful

5.3. Conclusions and next steps/recommendations from the activity

Aquifer storage and recovery (ASR) is a way of managing water resources to meet existing and future freshwater demands. It is the direct injection of surface water supplies such as potable water, reclaimed water (i.e. rainwater), or river water into an aquifer for later recovery and use. Simulated model on artificial recharge is thought to be very useful to generate alternative water source option in the Indian Sundarbans. Aquifer storage recovery (ASR) can be experimented with, some points to note in this regard are:

- ASR can prove to be a drought and cyclone resistant water resource
- ASR has the potential to reduce agricultural demand and competition for the 'sweet' water

- ASR Projects in Bangladesh have demonstrated Arsenic reduction and been used to improve water quality through filtration
- Filtration may be needed – which can lead to additional costs
- Untested longevity
- Depends on detailed lithology – small volume 'bubble' will have high surface area to volume in a thick aquifer

The participatory nature of this research project has highlighted the importance of ensuring stakeholder participation for successful understanding of the ground water dynamics and planning activities for resource sustainability. In this connection a participatory data repository along with community data sharing platform needs to be created with water users to regulate and maximize optimal use of fresh water.

The challenges moving forward are to field test the success of ASR systems, optimize system performance, and set expectations appropriately. In phase II of this project (if approved), conceptualized ASR technique will be executed in the field conditions under different scenarios testing the model performance.

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7. Annexes

Annex A: Community Workshops

Participatory Groundwater Management workshop at Sandeshkhali II:

This workshop was organized in Korakati Gram Panchayat of Sandeshkhali II Community Development Block. The main objective of the workshop was to initiate the pump priming project on aquifer study in the Sundarbans. The workshop was held in 13/06/2019 from 10.30am in the morning and ends with a lunch in the venue at 2.30pm. In the said workshop women and men leaders of Village Livelihood Committee (VLC), local Gram Panchayat members, administrators, engineer, assistant engineers, surveyors and GP's representative for water resource management were present and shared their views on their present situation of ground water.

Figure 11: Participatory groundwater management workshop

SDK II is one of 52 islands of Sundarbans with human population and the Community Development Block is located at 22°22'12"N & 88°54'08"E. Sandeshkhali II Community Development Block is part of the North Bidyadhari Plain, one of the three physiographic regions in the district located in the lower Ganges Delta. The area is full of marshes and salt water lakes. The Bidyadhari has a long course through the central part of the district. The wide Dansa, Kalindi and Raimangal rivers flow through the area. Sandeshkhali II CD Block has an area of 197.21 km2. It has 1 panchayat samity, 8 gram panchayats, 103 gram sansads (village councils), 24 mouzas and 24 inhabited villages. Sandeshkhali police station serves this block. Headquarters of this CD Block is at Dwarir Jangle. Offices of Sandeshkhali-II Block are: Sandedhkhali-II BDO Office, Sandeshkhali BLRO Office, Sandeshkhali ADA Office, Sandeshkhali II BLDO Office.

Total 25 participants participated and shared their views on how they manage the challenging seasons of winter and summer in the area. All the participants came from the three GPs of SDKII Block namely- Monipur, Bermajur II, Korakati.

Figure 12: Participants interactions at groundwater management workshop

Participatory Groundwater Management workshop at Gosaba:

Gosaba an important gate way to the core zone of Sundarbans and a community Development Block is located at 22°09’55”N & 88°48’28”E. It has an average elevation of 6 metres (20 ft) from the sea level. Total 31 participants participated in the workshop where women leaders came from six GPs 40% (6 out of 14 GPs) of Gosaba Block. All the participants came from the six GPs of Gosaba Block namely- Tentultali I, Tentultali II, Pathankhali, Bot-tala, Kumor Para, Jele Para.

The workshop was held in 14/06/2019 from 11am in the morning and ends with a lunch in the venue at 3pm. In the said workshop women leaders of local Self Help Groups (SHGs), local Gram Panchayat members, engineers, assistant engineers, surveyors and GP’s representative for water resource management were present and shared their views on their present situation of ground water.

After end of the session 6 volunteers came up to take the task of regular water sample collection from their field for isotope testing whom Dr. Gopal Krishan from NIH gave hands on training with water sample collection kit (sample water collection bottles, EC, pH & TDS tester).

Figure 13: Participatory groundwater management workshop

Figure 14: Participants interaction and samples testing

Annex B: Technical workshop

Groundwater Recharge, reduction in soil salinity and way forward for Indian Sundarbans:

Groundwater Hydrology Division of National Institute of Hydrology, Roorkee organized a workshop on "Groundwater Recharge, Reduction in Soil Salinity- solutions and way forward for Indian Sundarbans" on August 07, 2019 at ICAR-CSSRI, complex, Canning Town, Kolkata (Fig. 15) under IUKWC pump priming project in association with R. Prasari and BGS, UK. The livelihoods of the rural population of the Sundarbans are precarious, freshwater aquifers are deep, expensive to exploit and suffering over-exploitation. Farmers use ponds, filled during the monsoon for dry season irrigation, but these have limited capacity. An Aquifer Storage Recovery (ASR) approach that utilises saline aquifers adds resilience to the water supply system, without the challenges inherent in the management of the freshwater aquifers. The approach may be applicable beyond the deltaic systems studied, for instance in areas of irrigation induced salinity or geogenically contaminated aquifers.

Focused Group Discussion are required to get water level and quality parameters in the saline and fresh water aquifers and further the information will also be gathered from Rapid Rural Survey and field experiments conducted with barefoot-hydrogeologists in two blocks; Gosaba and Sandeshkhali II of Sundarbans West Bengal, India. The data on the saline aquifers will be integrated with available data for the deeper fresh water aquifers; data that has demonstrated deterioration in both yield and water quality as a result of over abstraction. The focused group discussions highlighted the principal water resource challenges facing farmers (Fig. 16-18). The stakeholders and scientists working in the targeted areas were brought in on platform by organizing this workshop. Workshop was attended by participants from CGWB, ICAR-CSSRI, Stakeholders, NIH-Roorkee, BGS, UK and Prasari.

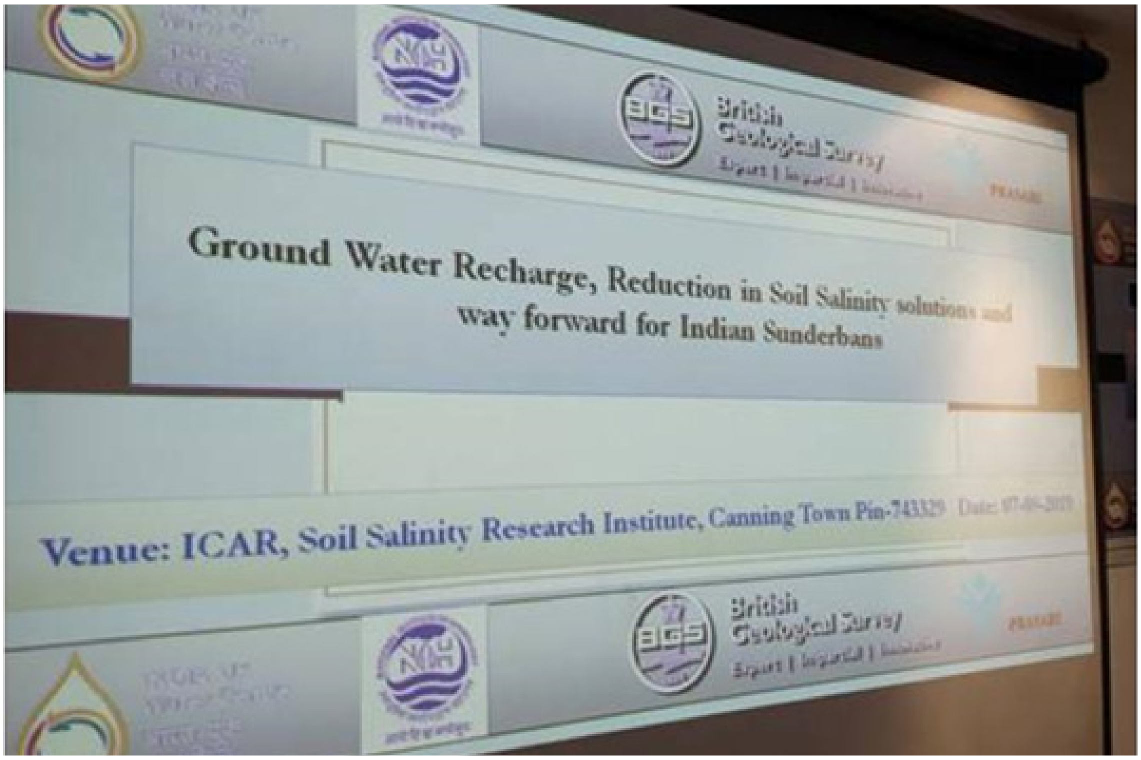

Figure 15: Workshop Banner

Figure 16: Introduction and presentation during workshop

Figure 17: Focused group discussion during workshop

Figure 18: Focused group discussion during workshop

On the basis of the soil and water problems faced in the study area, following solutions are suggested:

- Addition of organic matter
- Mulching
- Growing salt tolerant crops
- Liming for acid soils
- Rain water harvesting
- Awareness programes

It was decided that through participatory groundwater data collection approach, data will be collected on the following aspects -

1. Depth of saline aquifers, and lithological descriptions of the saline intervals
2. Properties of saline and fresh water aquifers
3. Cost of drilling to saline aquifers in the study area

Apart from participatory approach, field measurements will be taken on following -

- Estimates of aquifer properties such as grain size, permeability, water level and yield
- Estimates of the size of existing ponds in 'typical' farms (estimate wet season water availability)
- Salinity of saline aquifers, preferably taking samples of saline water if aquifers are accessible

Agenda: Day 1 - 7th August 2019

Topic	Points to be covered	Speaker and Organisation
Overview of Problems	What are the water related issues in Sundarbans?	Small group discussions
	Why present ground water scenario is so critical in Sundarbans?	
	Research objectives	
	Research design	
	Role of different stakeholders in the research?	
	Implementation methodology	
	Way forward	
Summarization of the findings	Summarization by Group A	PRASARI, CGWB, NIH, ICAR-CSSRI
	Summarization by Group B	
	Summarization by Group C	
	Summarization by Group D	
Sharing of field data collection from different sources	Data collection process	PRASARI, CGWB & ICAR-CSSRI
	Field data sharing by didis	
	Soil layers	
	Future target data collection	
	Collaboration plan with other research agencies to receive existing data	

Region Specific solutions for the region	Concept of ASR	Dr. McKenzie, BGS
	Sharing of past experiences on Artificial Recharge	Dr. Gopal Krishan, NIH
	Soil salinity reduction methods developed by CSSRI	Soil Salinity Research Inst.
	Process followed to include community in this research	Dr. Purnabha Dasgupta, PRASARI
	Experiences of CGWB	Dr. A.J. Kar
Way forward	Consolidation of the Primary ideas	Dr.McKenzie, BGS Dr. Gopal Krishan, NIH
	Date for next meeting on data review	
	Initiation of research consortium	
	Date of next meeting of this research Consortium	

Annex C: Information Dissemination workshop

Groundwater Hydrology Division of National Institute of Hydrology, Roorkee organized a workshop on "Understanding aquifer systems of Sundarbans- special emphasis on ASR using

Figure 19: Inauguration of workshop by Mr. P.K. Mishra, Principal Secretary; Commissioner MGNREGA

saline aquifers to improve farmers livelihood" on December 09, 2019 at Kolkata (Fig. 1) under IUKWC pump priming project in association with R. Prasari and BGS, UK. Indian Sundarbans comprises of 2 districts having 19 Community Development Blocks, 190 Gram Panchayats and 102 islands is the largest Gangetic delta in the Indian Subcontinent. . An Aquifer Storage Recovery (ASR) approach that utilises saline aquifers adds resilience to the water supply system, without the challenges inherent in the management of the freshwater aquifers. The approach may be applicable beyond the deltaic systems studied, for instance in areas of irrigation induced salinity or geogenically contaminated aquifers. In this workshop researchers, academicians and policy makers associated with Indian Sundarbans were invited to share their work experiences and vision for improvement of this region. The panel discussions were also held on the livelihood issues, soil and water conditions of Sundarbans and this workshop outcome are very much useful in development of some innovative techniques for management of soil and water of the region to improve the livelihood of the local inhabitants. Results of the project were also presented and very much appreciated.

The main objectives of the workshop were

- To identify livelihood issues faced by Sundarban farmers and future plans to tackle these issues
- Crop water management through resource integration
- Finalization of conceptual model of the island aquifer systems collating available evidence on aquifer extent

Workshop Participants

Workshop was attended by participants from Water Resources Investigation and Development Directorate, West Bengal (WRIDD), Panchayati Raj and Rural Development, West Bengal (PR&D), Centre Water Commission (CWC), New Delhi, Centre Ground Water Board (CGWB), Department of Enviornment and Forests, West Bengal, Department of Science and Technology, West Bengal, Jadavpur University, West Bengal, ICAR-CSSRI, Stakeholders, NIH-Roorkee, BCKV, Kalyani and Prasari. Participants from CWC were Deputy Director, Hydrology, Mr. Abhishek Gupta, Asstant Directors Mr. Ashish and Mr. Vipul (Coastal Management, Directorate) also attended the workshop.

- Participants were Government officials;
- Women leaders of the SHGs, GP members and others associated ground water of the area were invited by the field facilitator appointed for this project

Total 37 participants participated in the workshop.

Table 4: List of Delegates

	Organization name	Participant name	Designation/Role
1	Panchayat and Rural Development Department	Mr Kaushick Saha	Commissioner, MGNREGA
2	WRIDD	Mr Prabhat Kr. Misra	Principal Secretary
3	West Bengal Department of Science and Technology and Bio-Technology	Dr Dipankar Choudhury	Commissioner
4	Panchayat and Rural Development Department	Ms Suktishita Bhattacharya	Joint Secretary
5	Panchayat and Rural Development Department	Ms Indrani Sarkar	Deputy Secretary
6	Jadhavpur Univesity	Prof. S. Hazra	Professor
7	Bidhan Chandra Krishi Viswabidyalaya	Dr Lalu Das	Professor, Agri-Physics
8	Central Ground Water Board	Dr Amlanjyoti Kar	Regional Director
9	Central Soil Salinity Research Institute	Dr Dhiman Burman	Principal Scientist - ICAR
10	Central Soil Salinity Research Institute	Dr. Subhasis Mondal	Principal Scientist - ICAR
11	RKMVERI	Dr Rupak Goswami	Assoc. Prof.
12	WBDST-BT	Ms Subrata Dutta	Scientist
13	Centre Water Commission	Mr Abhishek Gupta	Deputy Director
14	Centre Water Commission	Mr Vimal Vijayanath	Astt Director II
15	Centre Water Commission	Mr Ashish Ranjan	Astt Director
16	Dept. of Environment and Forest	Dr Dipanjana Maulik	Sr. Scientist
17	WHH	Mr Anshuman Das	Programme manager
18	ICAR	Dr K.K. Satapathy	Retd Director
19	District Nodal Officer, MGNREGA - North 24 PGS	Mr Shubbhajit Ghorai	DNO
20	Asst. Engg., MGNREGA-North 24 PGS		Asst. Engg., MGNREGA
21	P&RD	Bododhyanti	GIS coordinator
22	National Institute of Hydrology	Dr Gopal Krishan	Scientist - C
23	National Institute of Hydrology	Mr A S Mehra	Personal Secy, Head GWHD
24	PRASARI	Mr Saikat Pal	Executive Director

25	PRASARI	Ms Sutapa De	Documentation officer
26	PRASARI	Dr Purnabha Dasgupta	Research Director
27	PRASARI	Mr Sashanka Gayen	Para-hydro-geologist
28	PRASARI	Ms Kalpana Howly	Para-hydro-geologist
29	PRASARI	Mr Gour Mondal	Para-hydro-geologist
30	PRASARI	Mr Gautam Banerjee	Research Assistant
31	PRASARI	Mr Dulal Mondal	Research Assistant
32	PRASARI	Ms Pradeep Naskar	Para-hydro-geologist
33	PRASARI	Ms Astami Mondal	Para-hydro-geologist
34	PRASARI	Ms Alpana Mali	Para-hydro-geologist
35	WBADMIP	Mr Sourabh Jyoti Gogoi	Training & communicating sp

Activity Structure

Activity started with welcome address, overview of programme and introduction by Dr. Gopal Krishan. Complete programme schedule is given as below:

Sr no	Topic/ Points to be covered	Speaker & Organization	Moderator	Panellists
1	Inauguration	Dr P K Misra, Principal Secy, WRIDD; Mr. Kaushick Saha Commissioner MGNREGA, Ms. Suktishita Bhattacharya JS. P & RD		
2	Overview of the programme and introduction	Dr Gopal Krishan, NIH		
3	Concept feasibility and modelling of the groundwater response	Co-PI: Dr. A. McKenzie, BGS	Ms Suktishita Bhattacharya	NA
4	Groundwater conditions of West Bengal	Dr Amlanjyoti Kar (RD CGWB)	Ms Suktishita Bhattacharya	NA
5	The livelihood issues facing Sundarban farmers	Dr Dipanjana Moulik, Scientist Dept. of Env. and Forest	Ms Suktishita Bhattacharya	Mr. Koushik Saha (Commissioner , MGNREGA) , Dr SubhasishMondal, Mr Saikat Pal, Ms. Suktishita Bhattacharya
6	Influence of monsoon on freshwater availability in Sundarbans under changing climatic conditions	Prof. Lalu Das, BCKV	Ms Suktishita Bhattacharya	NA
7	Panel Discussion on Crop Water Management in Saline Condition	Dr Purnabha Das Gupta Dr Burman ICAR-CSSRI	Ms Suktishita Bhattacharya	NA

8	Groundwater issues of the Sundarban	NA	Ms. Suktishita Bhattacharya	Parahydrogoeologists, Mr. Goutam Banerjee, Mr. Dulal Mondal, Dr. AmlanjyotiKar, Ms. Suktishita Bhattacharya
9	Overview of WRIDD on irrigation	Dr P K Misra	Dr. Gopal Krishan, NIH Ms Indrani Sarkar, Deputy Secy, P&RD	NA
10	Water Resource Assessment in Sundarbans	Prof. S. Hazra, Jadavpur University		NA
11	Artificial Recharge and Aquifer Storage and Recovery Introduction	Dr Gopal Krishan, NIH		NA
12	Soil conditions and water quality in Sundarban	Dr Dhiman Burman, CSSRI		NA
13	Next steps – a pilot study proposal	Dr Purnabha Dasgupta, Prasari		NA
14	Q & A session and interactions with the stakeholders			

Pres=Presentation; PD=Panel Discussion; Disc=Discussion

After the overview of the programme, Mr P.K. Mishra, emphasized on the issues of Sundarban, followed by panel discussion on topic "The livelihood issues facing Sundarban farmers" and the discussion was done as per below.

1. The livelihood issues facing Sundarbans farmers

Moderator: Dr Dipanjana Moulik, Scientist Dept. of Env. and Forest

Panellists: Mr Kaushick Saha (Commissioner, MGNREGA); Mr Saikat Pal, and Ms Suktishita Bhattacharya

1. A. Sir, what in your opinion are the livelihood related issues of Indian Sundarbans and how your team is working together to tackle those issues?

   B. Impact of MGNREGA on creating livelihoods of the people in Indian Sundarbans?

   C. Future plan under MGNREGA to attain sustainable development goals for Indian Sundarbans?

2. A. What problems farmers of Indian Sundarbans are facing right now?

   B. What strategies do you think can be taken to mitigate their problem?

3. A. How do you think MGNREGA can contribute to mitigate those issues highlighted by Mr. Pal?

   B. How in your opinion Govt. Dept.(s) and civil society organizations can work together to create a common platform to ensure participatory development in the area?

Figure 20: Panel discussion no. 1

Figure 21: Talks by invited speakers

After discussion, there were talks delivered by Prof. Lalu Das on “Influence of monsoon on freshwater availability in Sundarbans under changing climatic conditions”, Dr K.K. Satapathy on “Agricultural scenerio of West Bengal” and Mr A.J. Kar on “Groundwater conditions of West Bengal” Dr D. Burman on “Soil conditions and water quality in Sundarban” Prof. S. Hazra on “Water Resource Assessment in Sundarbans”, Dr. Purnabha on future prospects and are shown in Fig. 20. and 21.

2. Crop Water Management in Saline Condition

Moderator: Dr Gopal Krishan, NIH and Dr Punabha Das Gupta, Prasari

Panellists: Dr Dhiman Burman; Dr Lalu Das; Para-hydrogeologists; Ms Kalpana Maity; Mr Dulal Mondal; Prof. S. Hazra

1. A. Sir, what are the possible options for crop water management for small farmers of Indian Sundarbans?

   B. Sir, what in your opinion are the possible solutions to increase per drop crop productivity in Sundarbans’ context?

2. A. Sir, What measures CSSRI had taken so far to manage crop production under water stressed condition in Indian Sundarbans?

   B. What are the actions CSSRI had taken to manage crop production under submergence condition of Indian Sundarbans?

3. A. How resource integration can impact small farmers of Indian Sundarbans in managing production under water stress or submergence condition?

   B. What in your opinion are the sustainable ways to manage water for crop production in Indian Sundarbans?

4. A. How rainfall is impacting crop production in Indian Sundarbans?

   B. What measures farmers can take to tackle increased intensity of rainfall in the area?

3. Groundwater issues of Indian Sundarbans

Moderator: Dr Gopal Krishan, NIH and Dr Punabha Das Gupta, Prasari

Panellists: Dr Dhiman Burman; Dr Lalu Das; Para-hydrogeologists; Ms Kalpana Maity; Mr Dulal Mondal; Prof. S. Hazra

1. How ground water situation has changed over the years in your area?
2. What are the immediate problems related to ground water and salinity in your region?
3. What is the current situation of ground water in Indian Sundarbans?
4. How ground water use has changed cropping system in the area?

Second and third panel discussions were held on crop water management and ground water issues respectively as above.

Figure 22: Discussions during workshop

The workshop was very fruitful. Some useful tips were taken talks and deliberations by the researchers, academicians and policy makers and are given in the outcomes of the workshop.

Key themes/Points/outcomes arising

Main occupation is agriculture; cropping pattern paddy (Khanrif) and vegetables (Rabi); most of the times it is mono-croped; and some issues are: soil salinity; acid saline soils: water availability; climate change threats.

Conclusions and next steps

With the research output of the Pump Priming Project; National Institute of Hydrology, British Geological Survey and PRASARI designed the next phase of field experiment with the following objectives - i) Field testing of the model Aquifer Storage and Recovery (ASR) system in the saline aquifers of Indian Sundarbans, ii) Impact measurement of ASR in two different context through Ground water modelling, iii) Monitoring of the water quality parameters of the ASR water throughout the year, iv) Capacitating local cadres to facilitate water conservation in the islands of Indian Sundarbans and v) Dissemination of research outcome with the community and vi) Facilitating policy makers to use the research outcomes.

Stakeholders feedback

At the conclusion of the Activity, stakeholders from Sundarban were asked to provide comment on:

- The Workshop content; very much useful and all appreciated;
- The meeting venue and organisation; Venue was excellent and experienced it for the first time;
- Networking opportunities; happy to see all working in Sundarbans at one platform;

- Provide an overall score out of 10 for the workshop.

Stakeholders were very enthusiastic for implementation of next phase. They wanted it to be successful so that problems of getting sweet water/fresh water can be resolved to some extent.

Annex D: Water for Futures Conference

Feasibility of water storage in saline aquifers for drought resilience

Highlights

Deltaic coastal areas face challenges in dry season water availability, with brackish rivers and limited reservoir constructing opportunities. Water supplies and irrigation may depend on groundwater. In aquifers where confined saline layers are present aquifer storage and recovery can be developed to provide extra water resources during drought.

Summary

The Sundarbans area of West Bengal is an example of a deltaic system with islands where the population rely on groundwater for public supply and irrigation. Groundwater resources are supplemented by farm ponds, but the low relief means that reservoirs can't be constructed without excessive sacrifice of productive agricultural land. A multi-layered aquifer is present; the upper unconfined and confined layers normally saline. Deeper freshwater aquifers are heavily exploited, suffering from deteriorating yields and water quality. The potential of aquifer storage and recovery (ASR), where water is injected into the saline aquifers during the monsoon season, and recovered during dry months has been explored through a combination of participatory survey by local villagers and mathematical simulation. The project's conclusions will help guide pilot implementations of ASR as an approach to water management and to help increase community resilience to drought and cyclone induced flooding that periodically contaminates the farm ponds.

Figure 23: Dr. Andrew McKenzie Presenting in the International Conference at Bangalore organized by Water for Future

Introduction and objectives

Aquifer Storage and Recover (ASR) utilises aquifers as reservoirs, injecting water into the aquifer when excess supplies are available, and pumping it out when demand exceeds supply. When fresh water is injected into a saline aquifer a proportion of injected water will become brackish, but careful management will allow a high proportion to be recovered. The feasibility of using relatively small scale ASR systems on deltaic islands to provide resilience against drought and the periodic loss of surface water storage from cyclone driven flooding has been explored through aquifer characterisation and simulation.

Methodology

Water levels and water quality parameters in the saline and fresh water aquifers were determined based on information derived from Focused Group Discussion (FGD),

Rapid Rural Survey (RRS) and field experiments conducted with the barefoot-hydrogeologists in two blocks namely Gosaba and Sandeshkhali II of Sundarbans West Bengal, India. Field experiments were conducted at the farmers' field considering the depth of their bore wells and water samples were collected from different sources (with GPS information) to test water quality parameter like- presence of heavy metals, bacterial contamination, electrical conductivity, total dissolved solids etc. following standard operating procedures.

Why is the current approach/innovation relevant? What are the benefits and for whom?

The livelihoods of the rural population of the Sundarbans are precarious, freshwater aquifers are deep, expensive to exploit and suffering over-exploitation. Farmers use ponds, filled during the monsoon for dry season irrigation, but these have limited capacity. An ASR approach that utilises saline aquifers adds resilience to the water supply system, without the challenges inherent in the management of the freshwater aquifers. The approach may be applicable beyond the deltaic systems studied, for instance in areas of irrigation induced salinity or geogenically contaminated aquifers.

In this study, potential recharge activities such as – injection method etc. were identified for saline and fresh water aquifers. This in turn will provide a brief understanding of the gap in water demand and supply through recharge activities of the aquifers. Moreover, these results will also help farmers to plan their crops by realising the potential for aquifers' recharge and discharge capacity particularly during lean period.

Figure 24: National Conference in Hindi on Water Resource and Environment organized during December 16-17, 2019 and work under this project was awarded with the BEST PAPER AWARD

प्रपत्रः 4.8

सुंदरबन क्षेत्र में मिट्टी–पानी के मुद्दे और संभावित प्रबंधन

[1]गोपाल कृष्ण, [2]पूरनबा दासगुप्ता, [3]एंड्र मैकेंजी, [1]सी.पी. कुमार, [4]डी बर्मन, [4]यू.के. मंडल, [1]अंजू चौधरी

1 राष्ट्रीय जलविज्ञान संस्थान रुड़की, 2 राजारहाट प्रसारी, 3 ब्रिटिश जियोलाजिकल सर्वे, यू. के.
[4]ICAR–CSSRI, कोलकाता
ई–मेल : drgopal.krishan@gmail.com

सारांश

सुंदरवन की ग्रामीण आबादी की आजीविका अनिश्चित है और पानी की समस्या से जूझ रहे हैं । ताजे पानी के एक्वीफर गहरे हैं, और अत्याधिक शोषण से पीड़ित हैं। सिंचाई के लिए अच्छी गुणवत्ता वाले पानी की उपलब्धता जल स्तर में गिरावट के कारण एक समस्या है। किसान शुष्क मौसम में सिंचाई के लिए मानसून के दौरान भरे तालाबों का उपयोग करते हैं, लेकिन इनकी सीमित क्षमता होती है। पानी की समस्या के अतिरिक्त संपूर्ण क्षेत्र मिट्टी की लवणता से प्रभावित है। खरीफ सीजन के दौरान लीचिंग के कारण लवणता कम होती है लेकिन रबी मौसम में मुख्य रूप से जनवरी के बाद शुष्क मौसम शुरू होने से लवणता बढ़नी शुरू होती है और गर्मियों में नमक के जमाव वाले टुकड़ों को देखा जा सकता है। कुछ क्षेत्रों में एसिड सल्फेट और एसिड खारा मिट्टी पाई जाते हैं। एसिड सल्फेट मिट्टी उप सतह परतों में पाई जाते हैं ये मिट्टी खोदने के बाद सामने आती है, इससे फसलों पर असर पड़ता है, यह तालाबों में मछलियों की वृद्धि पर असर डालती है और इससे मछलियों की मृत्यु दर बढ़ जाती है। जलवायु परिवर्तन के कारण चक्रवात जैसी चरम घटनाओं और बदलते वर्षा वितरण आदि का उदय होता है। प्रस्तावित प्रबंधन उपायों में से कुछ इस तरह से हैं–खेतों में कार्बनिक पदार्थ की मात्रा को बढ़ाना; मल्चिंग; नमक सहिष्णु फसलों का चयन; एसिड मिट्टी के लिए लाइमिंग; वर्षा जल संचयन और जागरूकता कार्यक्रमों का आयोजन। एक्विफर स्टोरेज रिकवरी (एएसआर) दृष्टिकोण, मीठे पानी के एक्विफर्स के प्रबंधन में पानी की आपूर्ति प्रणाली में एक कारगर उपाय है।

Back cover image: Sundarbans (Emma Bennett, IUKWC)

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