केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण
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भारत सरकार

Central Ground Water Board
Department of Water Resources, River
Development and Ganga Rejuvenation,
Ministry of Jal Shakti
Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Malda District
West Bengal

पूर्वी क्षेत्र, कोलकाता
Eastern Region, Kolkata

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REPORT ON

AQUIFER MAPPING AND MANAGEMENT PLAN IN MALDA DISTRICTS, WEST BENGAL

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FOREWORD

Aquifer Mapping and Management programme was taken up by the Central Ground Water Board (CGWB) during the Xllth Plan to characterize aquifers in three dimensions and formulate an aquifer management plan for benefit of the stakeholders. With this objective, Aquifer Mapping and Management study was taken up in Malda district during the Annual Action Plan: 2019-20 and 2020-21. The management plans for fifteen Community Oevelopment Blacks of Malda district are prepared for sustainable management of groundwater resources through conjunctive use, increasing water use efficiency through novel methods and addressing the challenges of arsenic and fluoride contamination by critical analysis and interpretation of relevant data.

Hydrogeological, geophysical and hydrochemical data collected from field surveys was analysed using dedicated software to prepare thematic maps on aquifer geometry and cross-correlation and to assess suitability of groundwater for drinking and irrigational use for the benefit of the local populace. Non-committed surface runoff was estimated block-wise for adoption of rainwater harvesting and augmentation of water resources through managed aquifer recharge. Seasonal, annual and decadal fluctuations in groundwater level were depicted through thematic maps. A Public Interaction Programme was organized for benefit of the stakeholders, wherein outcomes of aquifer mapping and management study were presented. This was followed by knowledge sharing with the district administration with an objective to make informed decisions on planning and implementation of water conservation practices at district and block level. The primary objective of such programme and meeting was to adopt participatory groundwater management by the state government and the stakeholders with the philosophy *"Know Your Aquifer- Manage Your Aquifer".*

This report contains valuable information on aquifers of Malda district brought out through 2-0 cross-sections and 3-0 models along with specific recommendations to tackJe the challenging issues of arsenic and fluoride •contamination. I appreciate the efforts made by Sh. Oebasish Bagchi, Scientist-B (HG) in bringing out this report. I sincerely hope that it will be extremely useful to the policy makers, planners, administrators and groundwater data managers.

(Dr. Anadi Gayen)
Head of Office

EXECUTIVE SUMMARY

Aquifer Mapping and Management study was taken up in Malda district with an area of 3733 km^2. Quaternary alluvial sediments comprising Younger Alluvium (Aquifer Code: AL 01) and Older Alluvium ((Aquifer Code: AL 03) constitute the aquifers in the area, which occurs in the depth range of 17 m to 178 m. Older Alluvium is exposed in the Barind Tract characterized by thick layers of clay, deeper water level condition and relatively less groundwater potential as compared to the Younger Alluvium. The Barind Tract is conspicuous in eastern part of Malda district covering Bamongola, Habibpur, Gazole and parts of Old Malda community development blocks. Due to variation in lithofacies, aquifer geometry is not regular. Bore hole logs of Central Ground Water Board and state government departments (Public Health Engineering Directorate, Agri-Irrigation Department) have indicated a persistent clay layer, which is thinner in the northern, eastern and central part and thicker (> 10 m) in the southern part of the district. Aquifers consisting of medium to coarse sand and gravel are underlain by metavolcanic rocks of Garo-Rajmahal Gap at Araidanga (Ratua-II block), Mandilpur (Old Malda block) and Narendrapur (English Bazar block) in variable depth range of ~130 m to ~281 m. Based on subsurface lithological data of 53 Exploratory Wells and Tube Wells, two aquifer systems (Aquifer-1A and Aquifer-1B) have been identified, except in Habibpur, Old Malda and Harishchandrapur-II blocks where only a single aquifer system has been interpreted. This is also supported by interpretation of Vertical Electric Sounding data in Habibpur and Manikchak blocks. Geophysical study revealed that the recommended drilling depth of tube wells in Habibpur and Manikchak block should be between 40 and 180 m.

Drilling data of Exploratory Wells and Observation Wells has revealed highly variable discharge, ranging from 626.40 m^3/day at Bhaluka to 5034.53 m^3/day at Mandilpur. Drawdown was found to vary from 1.11 m at Bhaluka to 9.84 m at Nityanandapur, while transmissivity was ranging from 207.81 m^2/day at Narendrapur to 7170.0 m^2/day at Araidanga. Storage co-efficient of aquifer (depth 81 to 105 m) was 9.9×10^{-2} at Araidanga, indicating a semi-confined aquifer. Seasonal fluctuation in groundwater level indicated rise in 81.94% of the total number of monitoring wells, whereas decadal fluctuation revealed long-term rise in 94.44% of the wells in pre-monsoon and in 90.00% of the wells in post-monsoon. Significant long-term decline was not observed. Malda district is affected by arsenic contamination in groundwater (in eight blocks) and also by fluoride contamination (in two blocks). Data of CGWB has shown highest arsenic concentration of 0.402 mg/L at Sujapur in Kaliachak-I block and highest fluoride concentration of 4.54 mg/L at Sripur in Ratua-II block. Remediation of arsenic problem has been done through Arsenic Removal Plants installed by the Arsenic Area Water Supply Scheme of PHED. Five such water supply schemes dedicatedly commissioned for arsenic removal is functional in Ratua-I and Ratua-II block with a design population of 37710 and cumulative water supply of 4112 m^3/day. High iron concentration in groundwater was found in tube wells located in Manikchak, Bamongola, Gazole, English Bazar and Kalaichak-III block. However, groundwater was suitable for agri-irrigational use, which was confirmed from Wilcox Diagram and U. S. Salinity Diagram, with majority of samples falling under S1-C2 or S1-C3 class.

Adoption of demand side aquifer management may not be a priority due to low stage of groundwater development (<70%) for the entire district. However, Habibpur and Harishchandrapur-I blocks were categorized as Semi-critical (as on 31-3-2013) based on long-term declining trend in ground water level. However, subsequent assessment of dynamic groundwater resources (as on 31-3-2017) indicates that both the blocks are under Safe category. Managed aquifer recharge is possible in Kaliachak-I, Gazole and Old Malda blocks, that too in the shallow, unconfined aquifer (Aquifer-1A) occurring in the depth range of ~20 m to ~30 m. Feasible structures for implementing managed aquifer recharge (artificial recharge) are the percolation tanks, injection wells and recharge shafts in the pre-existing tanks and ponds. Estimation of block wise non-committed surface runoff for rain water harvesting and managed aquifer recharge shows high variability, with maximum volume of 83.86 MCM in Gazole block and minimum of 18.31 MCM I Kaliachak-I block. The calculations also show only 22.5% of the surface runoff can be utilized for recharge and harvesting. Based on monsoon rainfall data, the volume of rain water available for harvesting in 27 Census Towns of the district has been estimated at 0.003 MCM whereas for English Bazar and Old Malda Municipality, the estimated volume was 0.015 MCM.

It is possible to implement block level aquifer management plans with active participation of the district administration and the stakeholders. Cultivation of summer paddy needs to be reduced by at least 10% of the present production, especially in the Barind Tract where water scarcity in summer is a growing problem. Crops like peanut, maize, jute and soya bean needs to be grown, which have higher water use efficiency as compared to paddy. However, there should be a provision for crop subsidy by the state government keeping in mind the poor socio-economic conditions of the small and marginal farmers.

As a part of the celebration of 75 years of Indian independence through *Azadi Ka Amrit Mahotsav* programme, one Public Interaction Programme was organized on 28th July 2021. This was followed by a presentation of the Aquifer Mapping Study in Malda district in the office of the District Magistrate, Malda (in physical mode) on 15th November 2021. The outcomes of the present study was shared to the District Magistrate, Additional District Magistrate (General), Additional District Magistrate (Development), representatives from state government departments like Public Health Engineering Directorate, Malda Division and Arsenic Area Water Supply Division, State Water Investigation Directorate, Agri-irrigation Department and Agriculture Department. The possibility of dovetailing components of the aquifer management and water resources conservation can be explored through various central government and state government aided programmes like *Pradahan Mantri Krishi Sinchai Yojana – Har Khet Ko Pani, Jal Shakti Abhiyan – Catch The Rain, Jal Dharo – Jal Bharo* with active participation of the stakeholders. The central theme of developing a holistic aquifer management plan, whether in district, block or village level, should be *Know Your Aquifer – Manage Your Aquifer.* In order to achieve this, block wise Aquifer Management Plans of Malda district are being launched in web platform through Aquifer Information and Management System.

REPORT ON AQUIFER MAPPING, MALDA DISTRICT, WEST BENGAL

(AAP: 2019-20, 2020-21)

CONTENTS

REPORT ON AQUIFER MAPPING IN MALDA DISTRICT, WEST BENGAL
MALDA DISTRICT AT A GLANCE

S. No.	Items	Statistics
1.	**GENERAL INFORMATION**	
	Geographical Area	3733 km^2
	Co-Ordinates	Latitude - 24^0 40' 20" N to 25^0 32' 08" N Longitude - 87^0 45' 50" E to 88^0 28' 10" E
	Administrative Setup	
	➢ District Head Quarter	English Bazar ($25^0$00'14" N, $88^0$11'20" E)
	➢ Nos. of Sub-Divisions	2 (Malda Sadar and Chanchal)
	➢ Nos. of Blocks	15 (Kaliachak-I, Kaliachak-II, Kaliachak-III, Manikchak, Ratua-I, Ratua-II, English Bazar, Old Malda, Chanchal-I, Chanchal-II, Gazole, Bamongola, Habibpur, Harishchandrapur-I and Harishchandrapur-II)
	➢ Number of Gram Panchayat	146
	➢ Number of Gram Samsad	2008
	➢ Number of Mouza	1814
	➢ Number of Municipality	2
	➢ Number of Villages	3701
	(d) Population (Census, 2011) (with Population Density and Literacy %)	**Total: 3988845** Male: 2051541(51.43% of total) Female: 1937304(48.57% of total) Rural: 3447185 (86.42% of total) Urban: 541660 (13.58% of total) Population of Scheduled Caste: 835430 Population of Scheduled Tribe: 313984 **Population Density: 1069 person per km^2** Literacy: 52.30% Male literacy: 56.0% Female literacy: 48.0%
	(e) Normal Rainfall, Annual Rainfall & Temperature	Normal Rainfall: 1485.8 mm Annual Rainfall: 1297.9 mm (2019) 1614.4 mm (2020) Temperature: Maximum – 42^0C Minimum – 9^0C

2. GEOMORPHOLOGY

(a) Major Physiographic Units	(a) Barind (b) Diara or Younger Alluvium (c) Tal or Swampy Area
(b) Major Drainage	Perennial rivers: Ganga, Mahananda, Kalindri, Fulhar, Tangon

3. LAND USE (km²as on 31-3-2021)

Forest Area	16.79
Cultivable Area	2800.00
Net Cultivable Area	2599.21
Orchard & Horticultural Crops	750.00
Pasture & other Grazing Land	4.35
Cultivable Waste Land	0.86
Land under Non-Agricultural Use	817.67
Miscellaneous (Trees &Groves, not included in Sown Area)	28.53
Current Fallow Land	499.54
Other Fallow Land	2.04
Gross Cropped Area	4747.01
Net Sown Area	2343.19
Cropping Intensity	196.0 %

4. MAJOR SOIL TYPE	Red Soil, Lateritic Soil, Older and Younger Alluvial Soils
5. AREA UNDER PRINCIPAL CROPS (Year: 2016)	Cropped Area– 232160 ha Rice (Aus, Aman, Boro) – 204194 ha Total Cereals: 266173 ha Total Pulses: 2265 ha Total Food Grains: 288823 ha Total Oilseeds: 35951 ha Total Fibers: 22297 ha Total Miscellaneous Crops: 1049 ha
6. IRRIGATION	**Areas & No. of Structures (2016-17)**
(a) Minor Irrigation	
Tube Wells	**Heavy Duty Tube Well (HDTW)** Number: 326, Area Irrigated: 65.90 km² **Medium Duty Tube Well (MDTW)** Number:39, Area Irrigated: 4.89km² **Low Duty Tube Well (LDTW)** Number: 204, Area Irrigated: 13.54 km² **Shallow Tube Well (STW)**

		Number: 33616, Area Irrigated: 833.06 km^2
	Dug Well	Number: 0, Area Irrigated: 0
	Tanks/Ponds	Number: 30, Area Irrigated: 13.93km^2
	Surface Flow (weirs, diversions etc.) & Other Sources	Number: 466, Area Irrigated: 250.37 km^2
	Surface Lift from Rivers (RLI)	Number: 483, Area Irrigated: 96.14 km^2
	(b) Overall Irrigation Status	**Percentage of Irrigated Area to Cultivated Area – 55.04 %**
	Area irrigated by Groundwater	917.39 km^2
	Area Irrigated by Surface Water	360.44 km^2
	Net Irrigated Area	1445.88 km^2
	Total Irrigated Area	1277.83 km^2
7.	**NUMBER OF ACTIVE GROUND WATER MONITORING WELLS OF CGWB (as on 31.3.2021)**	89 Dug Wells – 56 Piezometer – 19 Tube Wells – 14
8.	**GEOLOGICAL FORMATION**	Younger and Older Alluvium
9.	**HYDROGEOLOGY**	
	Major Water Bearing Formation	Quaternary Alluvium
	Pre-Monsoon Depth to Water Level (2020)	➢ 2.28 to 15.27 mbgl in Dug Wells ➢ 3.65 to 27.79 mbgl in Piezometers/TWs
	Post-Monsoon Depth to Water Level (2020)	➢ 1.28 to 8.77 mbgl in Dug Wells ➢ 1.30 to 23.72 mbgl in Piezometers/TWs
10.	**GROUND WATER EXPLORATION (CGWB) as on 31-3-2021**	
	No. of Wells Drilled	8
	Depth Range (m)	Maximum depth drilled 280.51 m bgl
	Discharge (lps)	13.48 lps to 58.27 lps
	Storativity (S)	9.9 x 10^{-2} (in Araidanga OW, Ratua–II block)
	Transmissivity (T)	202.0 to 2969.0 m^2/day
11.	**GROUND WATER QUALITY**	
	(a) Presence of chemical constituents more tha permissible limit	Arsenic, Iron
	(b) Type of water	Ca-Mg-HCO_3
12.	**DYNAMIC GROUND WATER RESOURCES (as on 31-3-2017)**	
	(a) Total Annual Ground Water Recharge	233310.85 ham
	(b) Net Annual Ground Water Availability	99252.75 ham
	(c) Gross Annual Ground Water Extraction	113283.91 ham
	(d) Annual Ground Water Allocation for Domestic Use (up to 2042 AD)	5465.13 ham

	(e) Net Ground Water Availability for Future Use	99252.75 ham
	(c) Stage of Ground Water Development	53.09 %
13.	**AWARENESS AND TRAINING ACTIVITY**	
	(a) Number of Mass Awareness Programme Organized	Nil
	(b) Number of Water Management Training Programme Organized	One
14.	**EFFORTS OF ARTIFICIAL RECHARGE AND RAIN WATER HARVESTING**	
	(a) Projects Completed by CGWB (No. and Amount Spent)	Nil
	(b) Projects Completed under the Technical Guidance of CGWB (Nos.)	Nil
15.	**GROUNDWATER CONTROL AND REGULATION**	
	(a) No. of Over Exploited Blocks	Nil
	(b) No. of Critical Blocks	Nil
	(c) No. of Blocks Notified	Nil
16.	**MAJOR GROUND WATER RELATED PROBLEMS AND ISSUES**	(1) Arsenic contamination in eight blocks of the district. (2) Fluoride contamination in Ratua-II and Bamongola blocks. (3) Iron concentration in groundwater above permissible limit in major parts of the district, especially in tube wells.

1. INTRODUCTION

1.1 Location

Malda district, lying on the northern side of the River Ganga, is located on the Garo-Rajmahal Gap separating the deltaic West Bengal in the south and is underlain by Quaternary alluvial deposits of two different ages, namely Recent and Pleistocene.

The district lies between the north latitude 24^0 40' 20" N to 25^0 32' 08" N and east longitude 87^0 45' 50" E to $88^0$28' 10" E. Malda district falls in the Survey of India degree sheet nos. 72 O, 72 P, 78 C and 78 D. The district forms the northeastern part of the Indo-Gangetic alluvial plain and is flanked by the mighty river Ganga on its western and south-western boundary and by the international border with Bangladesh on the eastern and south-eastern boundary. The district is bounded by Pakur district (Jharkhand) in the west, by Purnea district (Bihar) in the north-west, by Uttar Dinajpur district in the north, by Dakshin Dinajpur district in the north and north-east and by Murshidabad district in the south. The terrain is generally flat with very low variation in surface relief with a gentle southerly sloping tract.

Malda district, the gateway of North Bengal and once the capital of Gour–Banga,is well connected by all-weather roads and railway to state capital Kolkata, national capital New Delhi and other parts of the country. Most of the trains that are bound for North Bengal and North Eastern states of India pass through Malda City Station located in the district headquarter Malda. Malda City is located on the confluence of the rivers Kalindri and Mahananda. Two National Highways, NH-34 and NH-31 pass through the district. Apart from this, state highways, a network of secondary and tertiary motorable roads connect various other prominent locations like Gazole, Habibpur, Manikchak, Harishchandrapur, Chanchal, Samshi, Ratua, Bamongola, Milki, Laxmipur, Kaliachak, Tulsihata etc. besides several large and small villages within the district. Total length of surfaced roads in the district was 4270.98 km whereas that of unsurfaced road was 4655.90 km (District Statistical Handbook, 2016).

1.2 Area and Administrative Units

The total geographical area of Malda district is 3733 km^2. The district has 2 Sub-Divisions consisting of 15 Development Blocks. There are 13 Police Stations, 146 Gram Panchayats, 2268 Gram Sansads, 3701 villages (out of which 1613 were inhabited) and 10641 habitations. The district itself is located on the southernmost part of North Bengal and falls under the Jalpaiguri Division. The district consists of two subdivisions –Malda Sadar and Chanchal. The district headquarters is in English Bazar, which is a prominent place of commercial activities. Other prominent locations in Malda Sadar Sub-division are Mangalbari, Sahapur, Nimasarai, Kamlabari, Old Malda etc. Important places in Chanchal Sub-division include Chanchal, Ratua, Tulsihata, Harishchandrapur, Barduary, Bhaluka, Malatipur, Pukhuriya etc. The administrative map of Malda district is shown in **Fig. 1.1.**

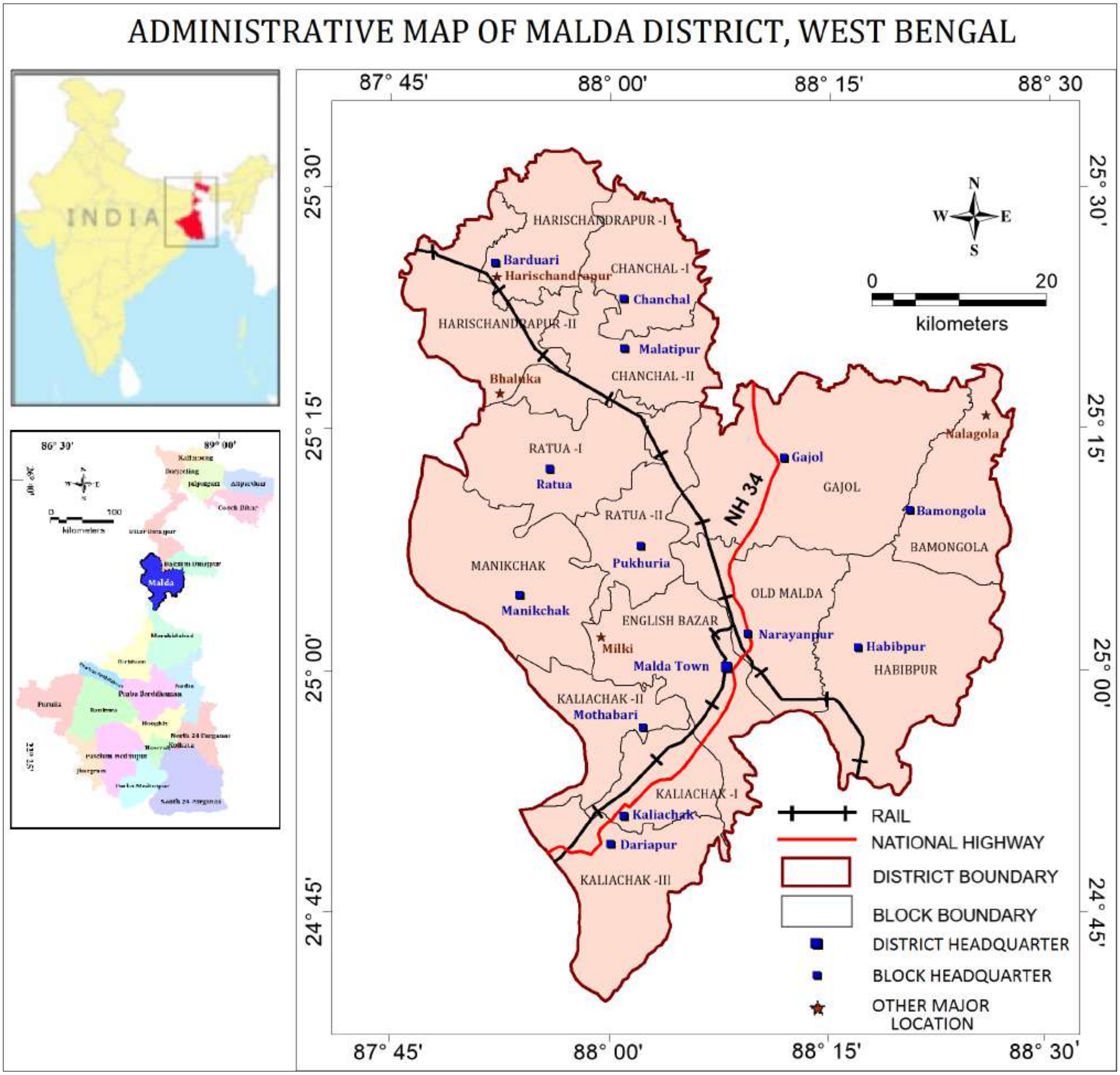


Fig. 1.1Administrative Map, Malda district

1.3 Demographic Details

As per the latest available data (Census, 2011), total population in Malda district was 3988845, out of which male and female populations were 2051541 and 1937304 respectively. The overall density of population was 1068 per sq. km. Rural population was 86.42% of the total population, whereas only 13.58% of population was urban population. The district recorded a sex ratio of 944 females per 1000 males. The major languages spoken in Malda district are Bengali, Urdu, Hindi and Maithili.

The overall literacy rate in the district is 61.73%, with male and female literacy rates being 66.24% and 56.96% (District Statistical Handbook, 2016). As per latest Census data, the percentage of Scheduled Caste and Scheduled Tribe in the total population were 20.94% and 7.87% respectively. A religion-based census has indicated that out of the total population, Muslim population was 59%, Hindu population was 40% and remaining 1% population was formed by people of other religion.

As per the economic condition, Malda district has been ranked as one of the most underdeveloped districts in West Bengal. Agriculture remains the main livelihood of the people, primarily due to the absence of any mineral resource in the district.

1.4 Land Use, Agriculture and Cropping Pattern

Net area under cultivation with respect to total geographical area for Malda district is one of the highest in West Bengal and has reached the optimum, leaving thereby a little scope for further extension of cultivated land. The ratio of net area sown to total area ranges between 49.4% in Kaliachak–I block and 95% in Chanchal–I block and the ratio is more than 75% in twelve blocks (out of fifteen) in the district.

Land use pattern of urban and rural areas mainly depends on socio-economic and socio-cultural factors. The change in land use pattern can be explained as follows:

1. The rapid growth of population demands for rapid increase in agricultural productions by bringing more and more areas under cultivation. In this regard, cropping pattern also plays a significant role as '*Boro'* paddy cultivation is gaining importance at unprecedented level through bringing more areas under this.
2. Rapid urbanization of the area is also changing the land use pattern regularly and more and more areas are being brought under urban activities and settlements.

Almost entire cultivated land is under double cropping with cropping intensity of 196%. Geomorphological conditions play an important role on land use and cropping pattern. In Malda district, agriculture is confined to 'Tal" or swampy area, "Diara" or flood plain area and "Barind" tract or relatively elevated land with occasional waterlogging condition. Swampy or 'Tal' area is mainly used for jute and paddy cultivation and its southern part is used for cultivation of '*Rabi*' crops, whereas '*Boro*' paddy (high yielding summer paddy) is produced in low-lying areas of 'Barind' tract. In 'Diara' or flood plain area (highly fertile), paddy is the main crop, though sugarcane, oil seeds, and barley are also grown. The junction of 'Diara' and 'Tal' area is extensively used for cultivation of various crops and for mango production. The year wise pattern of land use is summarized in Table 1.1.

Table1.1 Year wise details of Land Use, Malda district

Year	Geographical Area (ha)	Forest Area (ha)	Area under Non-Agricultural Use (ha)	Barren & Unculturable land (ha)	Permanent Pastures & other Grazing Land (ha)	Land under Misc. Tree Groves not included in Net Area Sown (ha)	Cultivable Waste Land (ha)	Fallow Land other than Current Fallow (ha)	Current Fallow (ha)	Net Area Sown (ha)
2002	371050	1680	84640	-	-	3050	90	300	52800	228490
2003	371050	1680	84060	-	-	3010	90	300	49650	232260
2004	370860	1680	83580	-	-	2990	100	310	54610	227590
2005	370860	1680	86720	-	-	2690	100	670	57460	221540
2006	370860	1680	84420	-	-	2900	100	300	70080	211400
2009	370860	1680	88620	-	-	3430	90	330	60710	216000
2010	370860	1680	90110	-	-	3240	100	300	57450	217980
2011	370860	1680	75280	-	-	2930	80	300	59520	231070
2012	370860	1680	80820	-	-	2930	90	300	53960	231080
2013	370860	1680	81250	-	-	2990	90	270	52420	232160
2014	370862	1679	81767	--	--	2853	86	204	49954	234319

Source: Directorate of Agriculture (Evaluation), Govt. of West Bengal

Agricultural Practices

Malda district is mainly agrarian**.** More than 87 % of the net cropped area is under paddy cultivation with rice being the staple food. Out of three varieties of paddy, *Aman* (autumn paddy) is grown over a large area. Crop production for *Aus* paddy, potato and barley are far below state average. However, productivity is at par or even more with state average for sugarcane, wheat and *Aman* paddy.

Cropping Pattern

The principal crops are paddy, potato, wheat, pulses, mustard and other oilseed, jute, sugarcane and other *Rabi* crops. Among the food grains, paddy is the principal crop. *Boro* and *Aman* are the main types. Jute cultivation ranks next to paddy. Among cash crops, mango ranks as principal fruit grown in 23179 ha. English Bazar is the best mango growing block. Other important mango-growing blocks are Manikchak, Harishchandrapur–I and II, Kaliachak–I, II and III and Old Malda. The district is famous for production of raw silk yarn, which annually gives 85% of total production of silk in West Bengal. Mulberry plantation, essential for production of raw silk yarn is found in the district's central and eastern part. The details of production and yield of principal crops is given in Table 1.2 (Source: Directorate of Agriculture, Govt. of West Bengal).

Table 1.2 Year wise variation in production and yield of principal crops, Malda district

	Crops	**2009-10**		**2010-11**		**2011-12**		**2012-13**		**2013-14**	
Food Grains		**Prod.**	**Yield**	**Prod.**	**Yield**	**Prod.**	**Yield**	**Prod.**	**Yield**	**Prod.**	**Yield**
1.	Rice	614.5	2834	630.5	3140	612.0	2986	644.6	3105	704.4	3544
	Aus	11.8	2031	5.5	1600	8.5	2317	5.5	1781	6.1	1943
	Aman	378.5	2647	379.5	2859	386.1	2671	412.6	2833	462.1	3407
	Boro	224.2	3296	245.5	3802	217.4	3835	226.5	3847	236.2	3935
2.	Wheat	129.4	2938	144.0	3027	131.8	3030	125.1	2784	131.7	2944
3.	Barley	1.4	1132	2.1	1378	1.9	1467	2.0	1419	1.9	1419
4.	Maize	19.9	2314	20.2	2299	29.4	2164	40.3	1979	42.7	2630
Total Cereals		765.2	2827	796.8	3081	775.1	2944	812.0	2960	880.7	3373
6.	Gram	4.8	1464	2.4	1074	3.8	1113	4.7	1446	3.6	1132
7.	Tur	0.1	1100	0.1	1094	<50 ton	448	<50 ton	1359	<50 ton	1286
8.	Other Pulses	18.9	1089	13.9	976	14.3	907	18.0	1016	17.9	967
Total Pulses		23.8	1149	16.4	989	18.1	943	22.7	1083	21.5	992
Total Food Grains		**789.0**	**2707**	**813.2**	**2955**	**793.2**	**2808**	**834.7**	**2827**	**902.2**	**3191**
Oil Seeds											
1.	Rapeseed & Mustard	38.4	1174	31.8	1047	36.6	1128	35.8	1062	38.3	1087
2.	Linseed	0.1	663	0.1	623	<50 ton	726	<50 ton	493	0.1	682
3.	Other Oil seeds	0.2	677	0.4	629	0.3	767	0.5	933	0.7	916
Total Oil Seeds		**38.7**	**1166**	**32.3**	**1035**	**36.9**	**1123**	**36.3**	**1059**	**39.1**	**1081**
Fibres											
1.	Jute	307.8	16.9	255.6	14.2	313.2	14.6	394.6	16.6	396.1	16.1
2.	Mesta	2.2	13.2	5.1	11.9	4.8	7.6	4.7	8.3	4.4	7.8
3.	Other Fibres	-	-	-	-	-	-	-	-	-	-
Total Fibres		**310.0**	**16.9**	**260.7**	**14.1**	**318.0**	**14.4**	**399.3**	**16.4**	**400.5**	**15.9**
Miscellaneous Crops											
1.	Sugarcane	212.8	98701	221.0	98925	253.9	116395	216.5	104567	210.2	102366
2.	Potato	151.8	34382	146.8	29153	147.0	38048	176.8	36077	164.7	32175
3.	Tobacco	0.1	657	0.1	656	0.1	650	0.1	658	-	-
4.	Chillies (dry)	2.8	1102	2.8	1105	2.8	1085	2.8	1086	2.9	1116
5.	Ginger	0.4	1593	0.4	1641	0.4	1642	0.4	1660	0.6	2162
Total Misc. Crops		**367.9**	**38726**	**371.1**	**36029**	**404.2**	**44418**	**396.6**	**39652**	**378.4**	**37694**

1.5 Irrigation Practices

Malda is endowed with vast groundwater resources. Groundwater is mainly tapped by shallow and deep tube wells. However, this resource is limited in 'Barind' tract. Irrigation facilities are also created from surface water sources like rivers, ponds and tanks. No major irrigation project exists in the district as per government data source. Irrigation infrastructure entirely depends on minor irrigation schemes. As per latest available data, no government irrigation canal exists in the district. Minor irrigation with surface water comprises river lift irrigation, irrigation from tanks and ponds. Total irrigated area in the district is 127783 ha, which is about 45.64% of cultivable area. Area irrigated by groundwater is 91739 ha whereas that by surface water is 36044 ha (District Statistical Handbook, 2016). Details of various sources of irrigation is given in Table 1.3.

Table 1.3 Irrigation by different sources, Malda district (area in thousand ha)

Year	Tank		HDTW		MDTW		LDTW		STW		RLI		ODW		Others		Total	
	Nos.	Area	Nos.	Area	Nos	Area	Nos.	Area	Nos.	Area	Nos.	Area	Nos.	Area	Nos.	Area	Nos.	Area
2009-10	255	1.333	326	6.568	39	0.450	145	0.886	33459	82.813	483	9.423	-	-	446	24.990		126.463
2010-11	255	1.323	326	6.606	39	0.459	145	0.903	33515	83.003	483	9.471	-	-	446	24.999		126.764
2011-12	255	1.391	326	6.570	39	0.468	192	1.248	33595	83.242	483	9.596	-	-	446	25.029		127.544
2012-13	255	1.389	326	6.585	39	0.477	192	1.256	33602	83.275	483	9.606	-	-	446	25.032		127.620
2013-14	255	1.393	326	6.590	39	0.489	204	1.354	33616	83.306	483	9.614	-	-	446	25.037		127.783

HDTW – Heavy Duty Tube Well
MDTW – Medium Duty Tube Well
LDTW - Low Duty Tube Well

STW- Shallow Tube Well
RLI - River Lift Irrigation
ODW – Open Dug Well

Source: 1) Irrigation and Waterways Directorate, Govt. of WB
2) Agriculture Office, Malda
3) Agri Mechanical & Agri Irrigation Department, Malda

Surface Water Irrigation: Sources of surface water are mainly the perennial rivers and streams. Small water bodies like pond, tank, *bils* are also important sources of surface water irrigation particularly during *Rabi* and *Boro* crop seasons. Apart from tanks, irrigation is also being done by surface flow schemes like weirs, diversions etc. Latest available data indicates that total area irrigated by surface water schemes is 36044 ha.

River Lift Irrigation: As per latest data of state government, a total of 483 river-lift-irrigation (RLI) schemes are operational in Malda district, where the water is drawn from major rivers like Ganga, Mahananda, Kalindri, Tangon and Punarbhaba. The command area for each scheme is about 25 ha. The total area irrigated by such RLI schemes is 9614 ha (District Statistical Handbook, 2016).

Irrigation from Ponds, Tanks and other Water Conservation Structures: Tanks, *Bills* and ponds irrigate a major part of the net irrigated area in water scarce area particularly in Barind tract, where ground water potential is comparatively low. These structures are also act as rainwater conservation structures. 255 tanks are now being used for Irrigation. In Bamongola block, more than 40% of net irrigated area is covered by tank due to absence of significant number of deep tube wells. Some tanks are used for non-irrigation purpose (for fisheries). Total area irrigated by tanks, bills and other surface water bodies is 1393 ha.

Groundwater Irrigation: Heavy Duty (HDTW), Medium Duty (MDTW) and Low Duty Deep Tube Wells (LDTW) and Shallow Tube Wells (STW) are the groundwater irrigation sources in Malda district. A total of 91739 ha of land is being irrigated by 326 HDTW (area irrigated: 6590 ha), 39 MDTW (489 ha), 204 LDTW (1354 ha) and 33616 STW (83306 ha). Details of irrigation sources like surface water irrigation, river lift irrigation and groundwater irrigation is given in Table1.4.

1.5 Urban area, Industries and Mining activities

There are two municipalities in the district namely English Bazaar and Old Malda covering an area of 22.63 km^2. Rapid urbanization brings more and more areas under residential and industrial sector. The district has no known mineral resources. The main industries present in Malda district are food products, wood, silk and synthetic fibre textiles, printing, publishing and allied industries, nonmetallic mineral products etc.

1.6 Economy of the District

Economy of the district is primarily based on agriculture. Main agricultural products are paddy, wheat, jute and rabi crops. Poor economy is due to low per capita income, low yield per acre of land, backwardness in industrialisation, shortage of capital and entrepreneurship and lack of infrastructure and large labour surplus. Production of raw-silk yarn in this district is about 85% of the total output of West Bengal, which amounts to about Rupees Four Crore annually. Production and trading of mango is another important aspect of the economy. About 45000 acres of land are covered by mango orchards which, in normal years, produces 360000 tonnes of mango with a value of around 5.5 Crore Rupees.

Table 1.4. Irrigation sources and area irrigated (ha) for each type, Malda district (Period: 2014-15)

Name of Block	Tank		RLI		DTW		STW		Others		Total	
	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
Harishchandrapur-I	-	-	14	378	33	395	3126	9294	25	1482	3198	11549
Harishchandrapur-II	-	-	42	535	11	170	4520	12490	12	705	4585	13900
Chanchal-I	6	33	26	419	32	686	2166	6940	36	1848	2266	9926
Chanchal-II	-	-	33	399	34	608	2250	6646	46	2235	2363	9888
Ratua-I	-	-	37	1021	40	692	2678	7048	16	986	2771	9747
Ratua-II	-	-	67	1431	79	1240	1449	3828	55	2953	1650	9452
Gazole	71	450	51	1060	91	793	4066	8049	65	3559	4344	13911
Bamongola	56	300	36	550	-	-	1892	4458	10	864	1994	6172
Habibpur	71	358	56	930	31	197	1856	3678	99	5607	2113	10770
Old Malda	51	252	51	1133	61	948	1201	2310	24	1529	1388	6172
English Bazar	-	-	25	580	50	1054	1098	2876	34	2021	1207	6531
Manikchak	-	-	27	701	21	482	2441	5546	10	555	2499	7284
Kaliachak-I	-	-	4	..	17	312	1340	2946	5	278	1366	3536
Kaliachak-II	-	-	11	385	26	440	808	1728	5	203	850	2756
Kaliachak-III	-	-	3	92	43	416	2725	5469	4	212	2775	6189
TOTAL	255	1393	483	9614	569	8433	33616	83306	466	25037	35369	127783

1.7 Previous Studies

Central Ground Water Board (CGWB) has completed Systematic Hydrogeological Surveys and groundwater exploration in Malda district. Systematic hydrogeological surveys were initiated by the Groundwater Division of Geological Survey of India during the period 1961-1967. Sh. M. Srivastava and Dr. D.K. Khan (1983) were the first to give a comprehensive hydrogeological account of the district. Subsequently, Reappraisal Hydrogeological Survey in Malda district was completed by Sh. Amlanjyoti Kar of CGWB during 1998-1999.

Under the All India Ground Water Exploration Project (1958-1959), exploratory drilling was undertaken at Mandilpur (Old Malda block), Kangsa (Bamongola block) and Nityanandapur (Habibpur block). During the Annual Action Plan: 2006-07, groundwater exploration was continued to delineate the geometry and characteristics of deeper arsenic-free aquifers under which exploratory drillings were carried out at Bhaluka (Ratua-I block and Harishchandrapur-II block), Araidanga (Ratua–II block) and Narendrapur (English Bazar block) where tube wells were constructed by tapping the aquifers using cement sealing technique for arresting the water supposed to be percolated from arsenic contaminated upper aquifer.

2. HYDROMETEOROLOGY

2.1 Climate

The district is characterized by a humid tropical climate, which is marked by extreme to very hot, oppressive and sultry summer (38^0 - 40^0 C), short and fairly cold winter and a protracted monsoon with plentiful rains and moisture in the air throughout the year. Basically, there are four seasons in the year. The period from March to May is the summer season. The rainy season starts in June with the onset of southwest monsoon and continues till the middle/end of September. October and the first half of November constitutes the autumn or post monsoon season. Winter starts in end of November and continues till end of February. December and January are the coldest months with temperature hovering in between 7 ^{0}C to 11 ^{0}C.

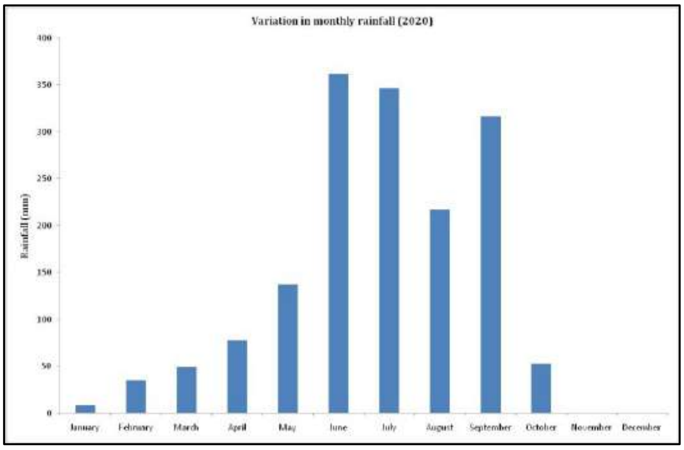
2.2 Rainfall

Normal rainfall in Malda district is 1453 mm whereas average number of rainy days (having daily rainfall exceeding 2.5 mm) in a year is 67. Main source of rainfall is the southwest monsoon, which contributes 78 % of the total annual rainfall. Maximum rainfall is recorded in July and August, whereas November, December and January are mostly dry. Sometimes torrential rain for short duration occurs from March to May. Eastern part of the district receives more rainfall than the western part. Monitoring of rainfall is done by India Meteorological Department in Malda City and also by the State Government through eight rain gauge stations located mostly in Block Seed Farms. Month wise rainfall data for five years (period: 2016-2020) is given in Table 2.1 and a bar diagram for the monthly rainfall data of 2016 is shown in Fig. 2.1.

Table 2.1 Month wise Rainfall data, Malda district

Month	Rainfall (mm)					
	2016	2017	2018	2019	2020	Average
January	16.9	0.9	0	0	8.3	5.22
February	0	0	7.6	38.1	35.1	16.16
March	2.1	12.4	22.9	3.6	49.0	18.0
April	21.6	94.8	112.0	77.0	77.8	76.64
May	85.4	110.6	153.6	121.1	137.5	121.64
June	157.4	76.5	85.3	98.8	361.9	155.98
July	407.3	352.6	230.2	373.5	346.5	342.02
August	152.1	580.5	148.9	104.0	217.4	240.58
September	337.9	200.1	133.4	364.9	317.0	270.66
October	72.0	143.9	51.2	145.6	52.7	93.08
November	12.3	0	0	0	0	0
December	8.3	5.7	12.3	1.3	0	3.86

Source: India Meteorological Department



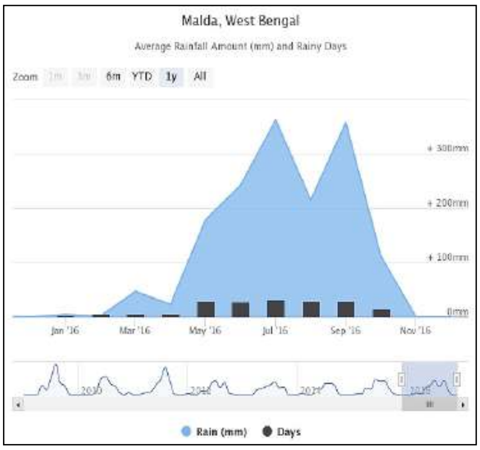


Fig. 2.1 Monthly Rainfall (2016) and Average Rainfall with Rainy Days (2016), Malda City

2.3 Temperature

Mean annual temperature of the district is 25 ^{0}C. Late December and early January are marked as the coolest period when minimum temperature generally remains around 7 ^{0}C to 11 ^{0}C, which sometimes goes down to 4 ^{0}C. In winter, day temperature scales around 25 ^{0}C to 27 ^{0}C. May is the hottest month with temperature soaring as high as 43 ^{0}C. Generally, temperature rises from the beginning of March and day temperature goes up to 40 ˚C in April and May. Mean minimum and maximum temperature in the district are 22 ^{0}C and 31 ^{0}C respectively. The monthly minimum, maximum, monthly mean minimum and monthly mean maximum temperature (period: 2010-2014) is given in Table 2.2 and Table 2.3. The minimum, maximum and average temperature at Malda City is shown in **Fig. 2.2.**

Table 2.2 Yearly minimum and maximum temperature (°C), Malda district

Month	**2010**		**2011**		**2012**		**2013**		**2014**	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
January	26	8	26	5	28	10	27	5	27	9
February	32	13	31	13	34	11	32	13	30	10
March	40	19	37	15	39	17	38	17	38	16
April	41	22	39	19	41	20	42	19	41	22
May	42	21	37	21	43	21	43	22	42	21
June	40	22	37	25	42	25	37	22	38	22
July	36	26	35	25	36	26	36	26	36	25
August	38	26	37	24	36	26	36	25	34	25
September	35	25	37	25	..	..	37	24	36	24
October	35	22	35	20	35	20	34	22	35	22
November	34	17	32	17	32	15	31	16	33	16
December	30	9	31	9	27	8	29	10	28	9
Annual	**42**	**8**	**39**	**5**	**43**	**8**	**43**	**5**	**42**	**9**

Table 2.3 Month wise mean minimum and maximum temperature (^0C)

Month	2010		2011		2012		2013		2014	
	Mean Max	Mean Min	Mean Max	Mean Min	Mean Max	Mean Min	Mean Max	Mean Min	Mean Max	Mean Min
January	21	11	21	11	23	13	22	11	23	13
February	28	16	28	16	28	16	28	16	25	15
March	35	22	33	21	34	20	34	21	32	20
April	37	26	34	23	35	24	35	24	37	24
May	35	25	34	25	38	27	34	25	38	26
June	34	26	34	26	36	28	34	27	34	27
July	33	27	33	27	33	27	34	28	33	27
August	34	27	32	27	34	28	33	27	33	27
September	33	26	33	26	..	..	34	27	32	26
October	32	24	33	25	32	24	31	24	32	24
November	30	21	29	20	28	18	29	19	30	19
December	25	14	24	14	22	13	25	15	23	13

Source: India Meteorological Department

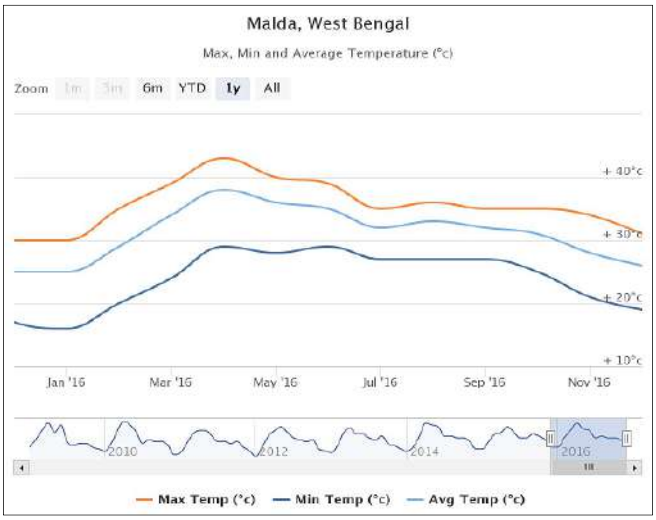


Fig. 2.2 Maximum, Minimum and Average Temperature in Malda City (2016)

2.4 Humidity

The district has a humid climate throughout the year and humidity ranges between 54 to 84 % as recorded at 8:30 AM. Maximum relative humidity (RH) varies from 54 to 94% whereas the minimum RH varies from 35 to 80%. The relative humidity is the maximum during monsoon season in the month of August and the minimum in spring viz. during the months of February and March. Graphical representation of average Clod Cover and Relative Humidity in Malda City (Year: 2016) is given in **Fig. 2.3.**

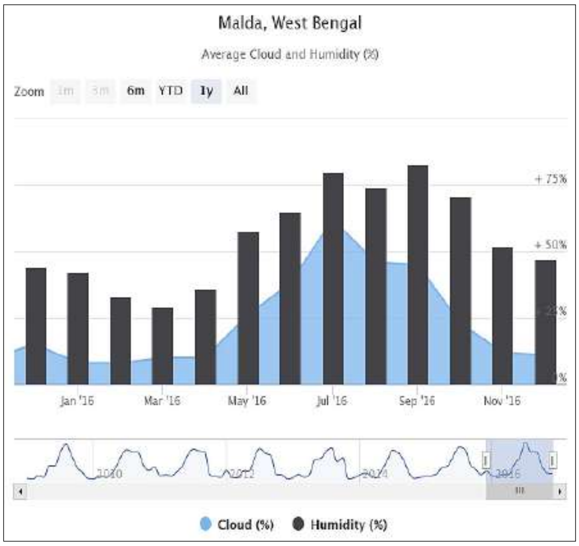


Fig. 2.3 Average Cloud Cover (%) and Relative Humidity (%) in Malda City (year: 2016)

2.5 Wind Velocity

Wind velocity varies from month to month and it attains maximum value during the winter months of November to January. Sometimes cyclonic wind and hailstorms lash the districtin the months of March-April. Wind speed plays an important role in the evaporation and evapo-transpiration process.

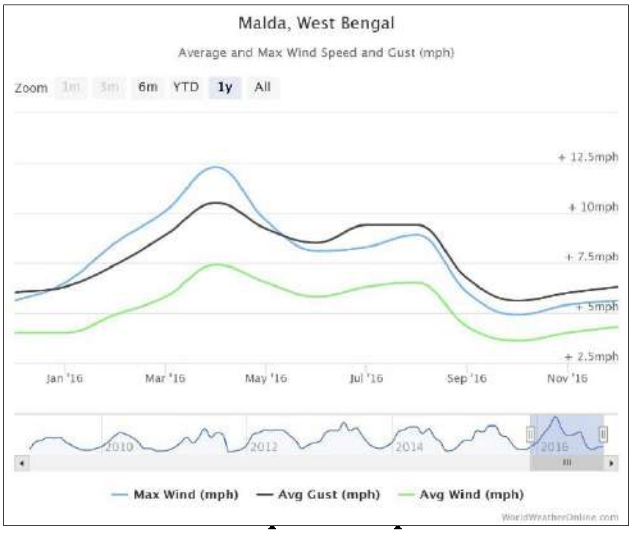


Fig. 2.4 Average and Maximum Wind Speed and Gust (mph) in Malda City (year: 2016)

Specific data on Potential Evapo-transpiration (PET) are not available for the district. However, in the month of May, Precipitation (P) exceeds 0.5 times the Potential Evapo-transpiration (PET) indicating favourable moisture condition for germination of clouds. The period wherein P is greater than PET is known as humid or wet period. In this condition, precipitation (P) exceeds the Potential Evapo-transpiration (PET) demand of crop and replenishes the moisture deficit in storage. Humid period commences in the last week of May and continues up to first week of October. During post-humid period (after the first week of October), precipitation is less than Potential Evapo-transpiration and soil moisture starts declining. In Malda City, recorded lowest and highest normal Potential Evapo-transpiration (year: 2016) are 61.2 mm in December and 187.6 mm in May. The total annual Potential Evapo-transpiration in Malda district was 1363 mm in 2016.

3. GEOMORPHOLOGY

3.1 Physiography

Malda district is characterized mainly by low-lying plains, sloping towards south with undulating areas on the northeast having a flat to gently rolling topography, with an elevation varying from 22.0 m to 39.7 m above mean sea level (amsl). The highest elevation of 39.7 m amsl is located at Gazole in the east central part of the district.

Mahananda River divides the district into two regions - the eastern region, consisting mainly of older alluvial and relatively unfertile soil, is commonly known as the 'Barind' tract. The western region is further subdivided by Kalindri River into two areas. The northern part is known as 'Tal' and the southern part is known as 'Diara'. Thus, the district can be divided into three distinct geomorphic units namely Barind, Diara and Tal, which are local terms but deeply entrenched into standard literature. A brief description of the three geomorphic landforms is given below.

3.1.1 Barind: The Barind tract is peculiar due to its physiographic characteristics. It is predominantly developed in Bamongola, Gazole, Habibpur and Old Malda blocks in the eastern and east central part of the district. The Barind tract consists of relatively unfertile older alluvial soil exposed in relatively elevated highlands with wide undulating tract and interspersed between shallow stretches and deeper depressions. This zone consists of reddish brown, clayey soil.

3.1.2 Diara: The flat, very fertile and thickly populated land between the Ganga River on the west, Mahananda River on the east and Kalindri River on the north comprises younger and older alluvial plains, which is locally known as Diara. This unit is the result of accretion of flood plain deposits. In this zone, the soil is predominated by loam followed by sandy loam. It is well developed in English Bazar, Manikchak and Kaliachak–I, II and III blocks.

3.1.3 Tal: The zone falling in the western part of Mahananda River and northern part of Kalindri River covering Ratua–I and II blocks and Harishchandrapur-I and II blocks, is locally known as Tal or swampy area. This is a low-lying area sloping down towards south and is vulnerable to inundation during monsoon period. Soil in Tal is of clayey loam type. Several depressed, swampy areas, locally known as *Bils* are frequently observed in the Tal zone. The largest of such *Bils* is the *Ahora Bil* covering an area of about 5 km^2 in the southwest of Barind Tract in Bamongola block. A series of such *Bils* is exposed in a linear pattern to the east of Mahananda River, extending from English Bazar to Gour. Isolated *Bils* are also found in the flood plains or Diara zone.

Geomorphological map of Malda district is shown in **Fig. 3.1**, which shows four geomorphic class viz. alluvial plain, active delta plain, meander flood plain and marshy/inundated plain. Majority of land surface in the district has a very low slope (< 5 m/km) except for the Barind tract in parts of Bamongola, Habibpur and Gazole blocks, where the slope is higher (5-10 m/km). The Relief and Slope map of Malda district is shown in **Fig. 3.2.**

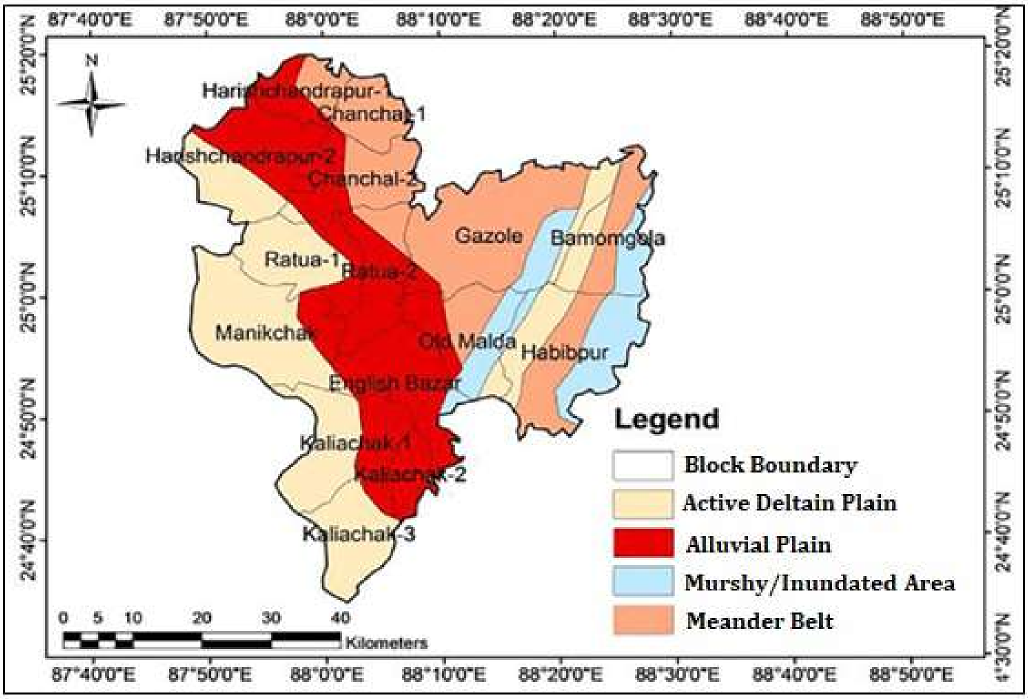


Fig. 3.1 Geomorphological map of Malda district

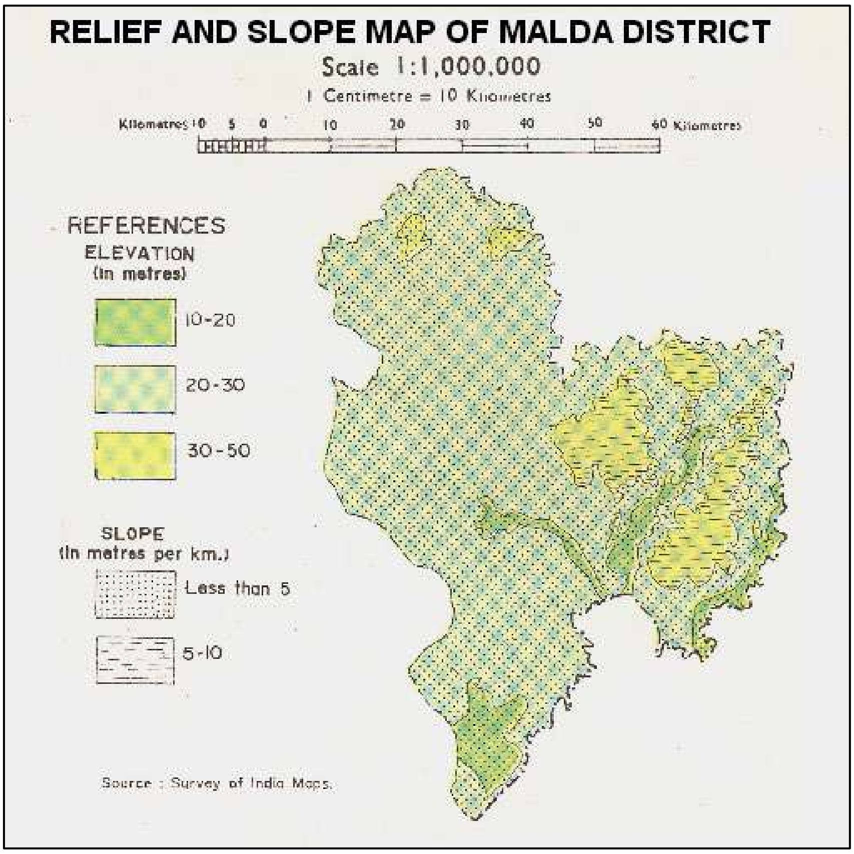


Fig. 3.2 Relief and slope map of Malda district

3.2 Land Use Land Cover

Land cover is the natural class of landform whereas land use is the usage pattern by human for a particular land cover type. Although these two terms are often used together, the natural classes like forest land, wetland etc. are distinct from human made classes like built-up area, agricultural land etc. Water bodies can be both natural like rivers and streams, large ponds (*Bils*) as well as artificial like irrigational tanks and ponds, canals etc. In Malda district, major land use/land cover types are agricultural land, water bodies (rivers, streams, ponds), wetlands (marshy and seasonally inundated areas comprising the *Tal* zone), forest land and built-up area (human settlements). Land Use Land Cover map of Malda district is shown in **Fig. 3.3.**

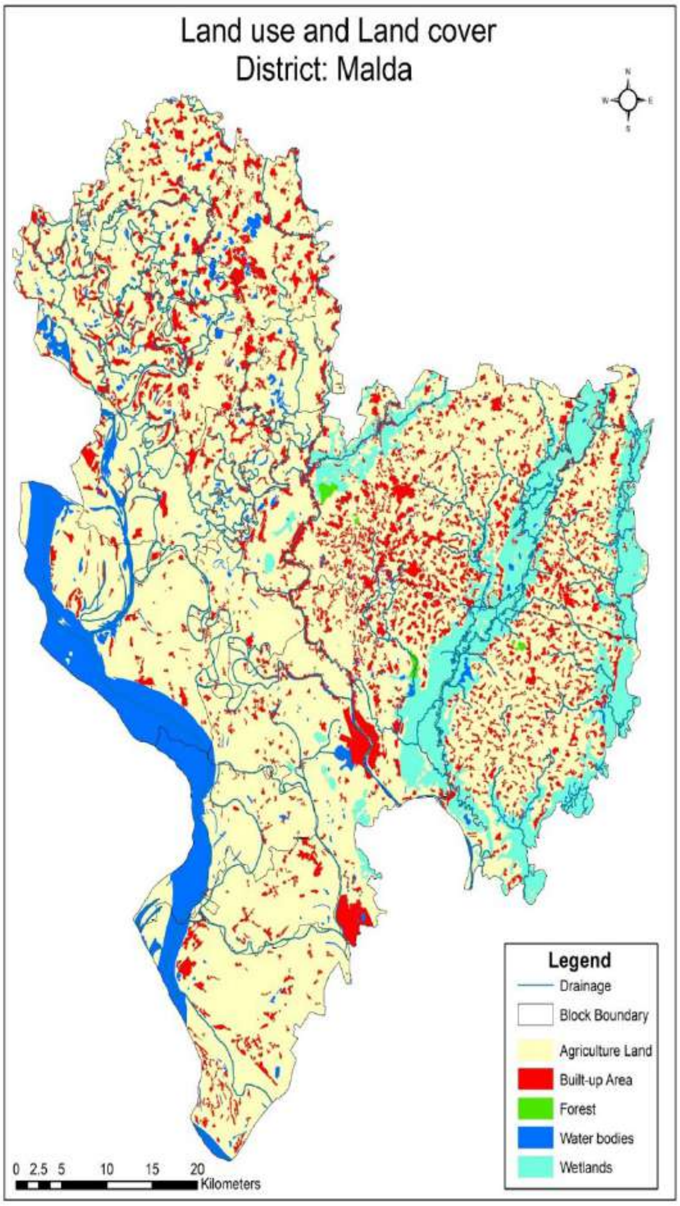


Fig. 3.3 Land Use Land Cover map of Malda district

3.3 Drainage

The most important natural drainage in Malda district are the major perennial rivers like Ganga, Fulahar, Mahananda, Kalindri, Tangon, Nagri and Punarbhaba, which constitute the main drainage system. Ganga and Mahananda rivers constitute the largest drainage network in the district. Almost all the major rivers are meandering in nature and have left typical ox-bow lakes along their abandoned channels. These rivers played an important role in overall geomorphological set-up of the district. Drainage map of Malda district is shown in **Fig. 3.4.**

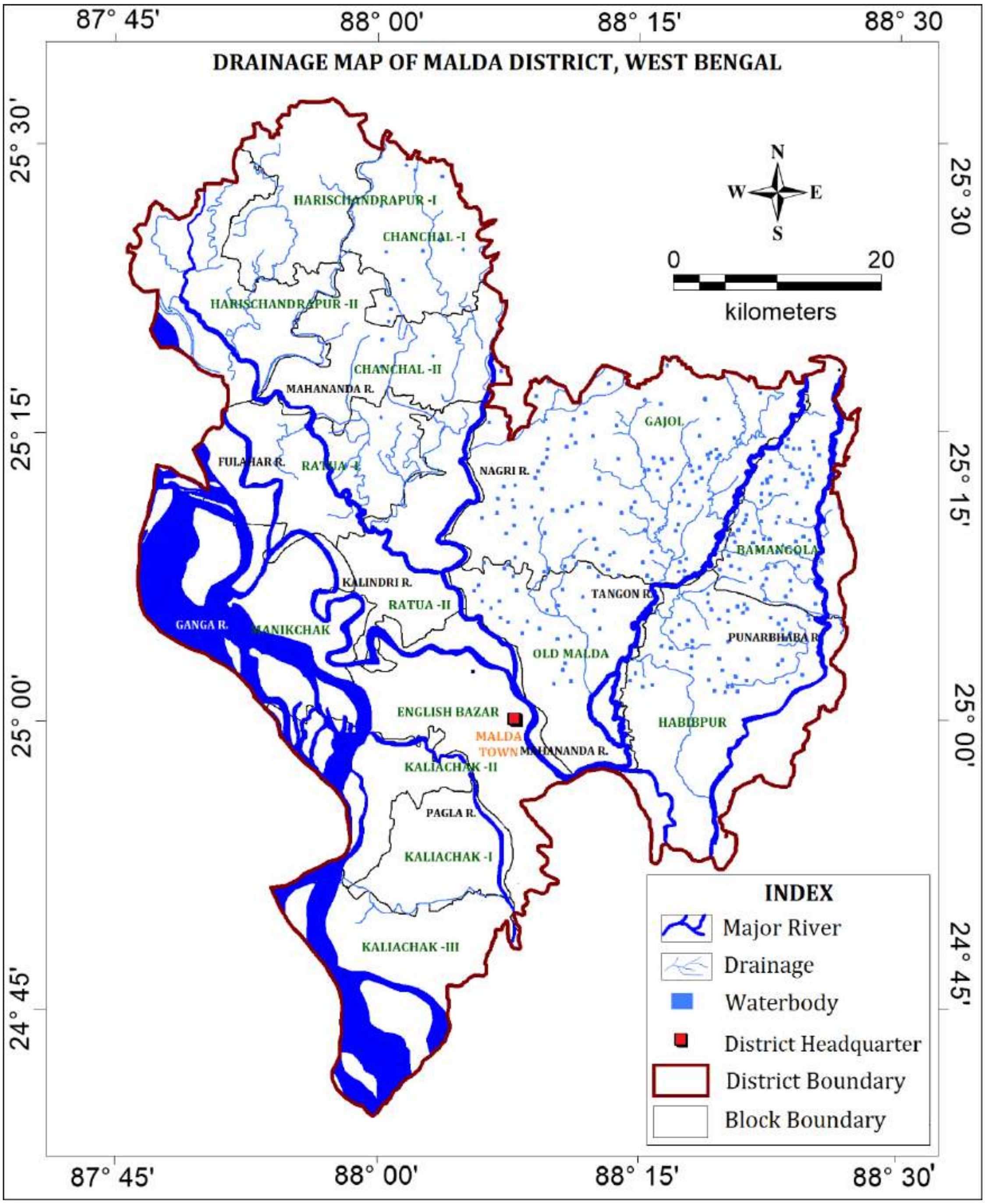


Fig. 3.4 Drainage map of Malda district

Ganga River marks the western and south-western boundary of the district and flows south easterly through Manikchak block and western boundary of Kaliachak-I and II blocks for 172 km before entering Bangladesh. It drains only the western and south-western parts of the district. Tributaries of Ganga River in Malda district are Fulahar and Kalindri. Mahananda River enters Malda district through the tri-junction of Chanchal–I, Ratua–II and Gazole blocks and drains the central part. The river flows from north to south for 88.6 km before entering Bangladesh. It divides Malda district into a) the eastern part having higher altitude and b) the western part having lower altitude. Punarbhaba River enters from northeast of Bamongola block, flows along with its tributary Haria Nadi for 64.4 km before entering Dakshin Dinajpur district. Tangon River enters the district at the junction of Bamongola and Gazole blocks, then flows south easterly through the Barind tract and meets Mahananda River near Muchia in Habibpur block. Kalindri River flows through English Bazar and Manikchak blocks and joins Mahananda River to the north of Malda City. Tangon River divides the Older Alluvial area (Barind Tract) into two parts a) Bamongola and Habibpur blocks with large water bodies in the east and b) Gazole and Old Malda blocks in the west.

3.4 Soil Type

Soils of Malda district can be divided into two groups, a) gangetic alluvial soil and b) red soil. Mahananda River separates the gangetic alluvial soil in the western part from the red soil in the eastern part. Gangetic alluvial soil is further sub-divided into three types based on texture, namely a) Gangetic riverine soil which occurs in Harishchandrapur-I and II, Manikchak, Kaliachak-I, II, III and western part of Ratua-I block, b) Gangetic flat land soil which occurs mainly in Chanchal-I and II, Ratua-II and parts of Gazole, Old Malda and English bazar blocks and c) Gangetic low land soil, which occurs in Ratua-I and Chanchal-II blocks.

Gangetic alluvial soils have one or two sandy layers made up of fine to very fine sand of grey and greyish white colour. The soil is rich in calcium and almost neutral in reaction. Clay content is fairly high whereas organic matter, potash and phosphorous contents are low to medium. The soil is fertile and used extensively for cultivation especially for paddy, jute, pulses and oil seeds. Main constituents of this soil are – sand: 7-9%, sandy loam: 15-16%, loam: 45–47%, clay loam: 5-13%, silt loam: 11-12% and clay: 5-6%. It is very fertile and used extensively for cultivation of paddy, jute, pulses and oil seeds (Ghosh Dastidar and Adhikari 2008). The red soil occurs in eastern part of Malda district, covering the '*Barind*' tract. It is reddish to reddish brown in colour. Constituents of this soil are - sandy loam: 0.5%, loam: 10-12%, clay loam: 32-35% and clay: 55-57% (Ghosh Dastidar and Adhikari 2008). The soil is mildly acidic with low organic matter and phosphate content. It is also fertile and suitable for high yielding paddy (*Aman* and *Boro*), jute and *Rabi* crops. Soil map of Malda district depicting four principal categories, is shown in **Fig. 3.5.** This map shows three soil classes based on texture, viz. fine loamy, coarse loamy and fine silty soil. Fine loamy soil is exposed in major part of the district whereas fine silty soil occurs in the eastern and southern most parts. Coarse loamy soil occurs as scattered patches in the northern, western and south central parts.

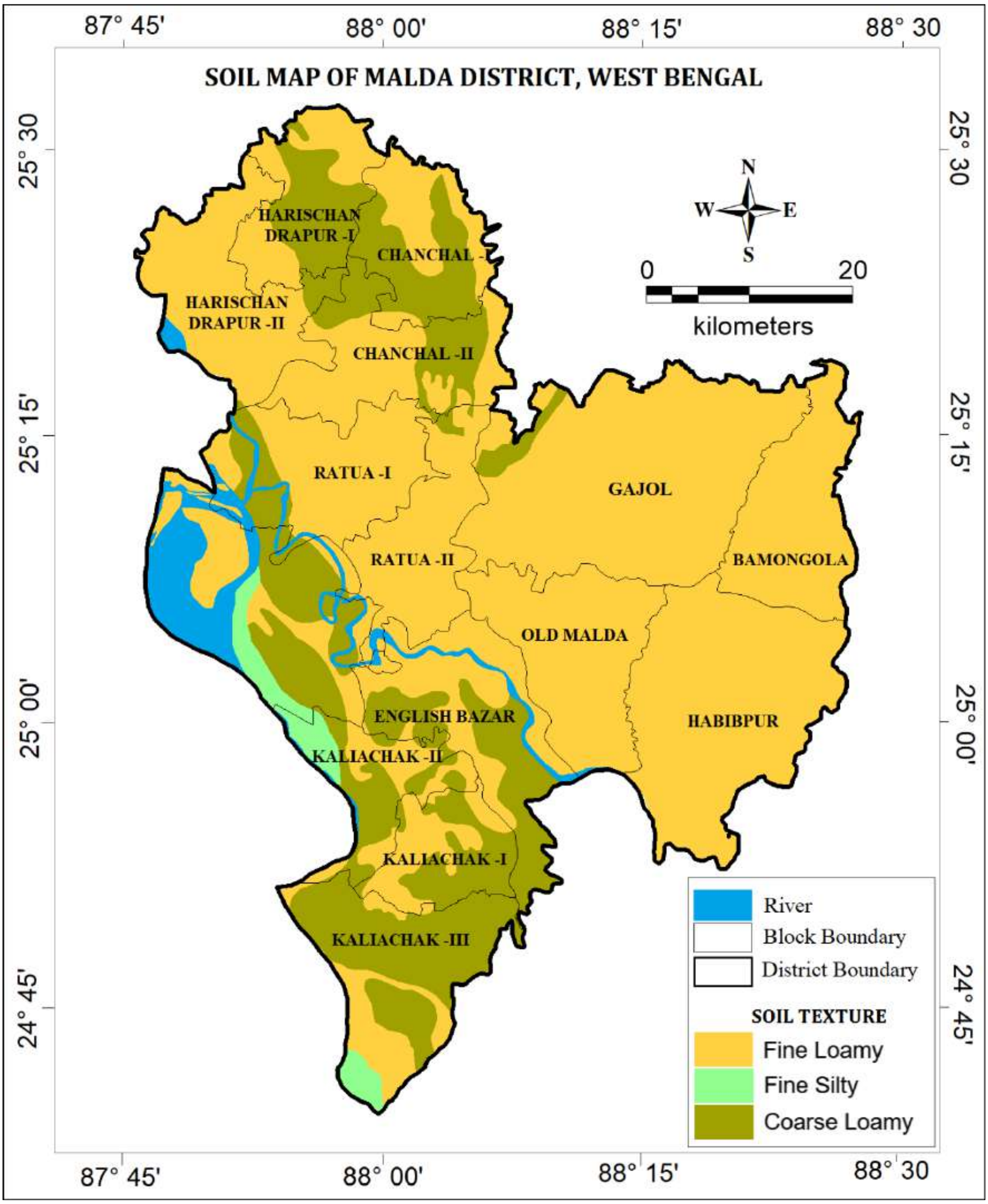


Fig. 3.5 Soil map of Malda district

4. GEOLOGY

4.1 Surface Geology

The geological setting of Malda district is a result of subsidence and concomitant deposition in Garo-Rajmahal Gap in the fore deep area in front of the Himalaya. Large scale sedimentation by the Himalayan rivers in Pleistocene and Holocene (Recent) periods deposited alluvial sediments of two age groups namely Older Alluvium of Pleistocene age and Younger Alluvium of Holocene age.

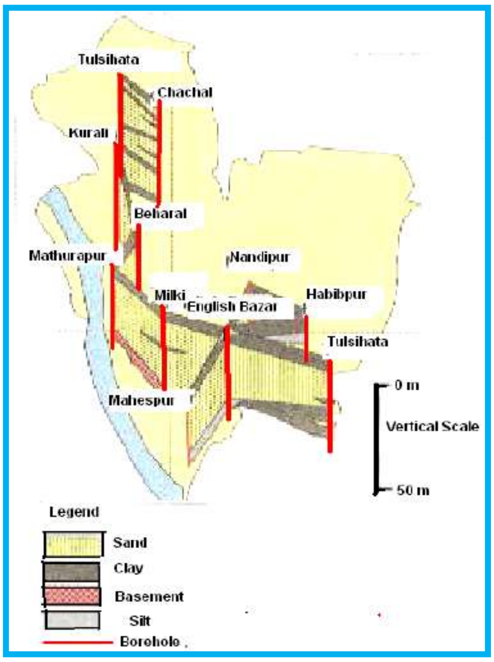
Older Alluvium of Pleistocene age occupies the eastern part of the district covering Gazole, Habibpur, Bamongola and Old Malda blocks. This alluvium is composed of argillaceous sediment (clay) and calcareous material, which has imparted a reddish brown colour to the soil as the lateritisation of sediment is often observed in surface clay. The clays are very stiff and plastic in nature.

Younger (or Newer) Alluvium of Holocene age is exposed in western part of the district to the west of Mahananda River, which has a fairly thick sedimentary succession deposited in the deltaic flood plains. The fluviatile sediment is characterized by dark grey colour, high moisture and organic matter content, which consists of a sequence of clay, silt, micaceous sand (fine to coarse grained) and sub-rounded to rounded gravel. In Barind tract, older alluvial deposits occur along Tangon and Punarbhaba Rivers.

4.2 Subsurface Geology

Subsurface lithological data collected from several tube wells drilled by State Govt. agencies and from the exploratory boreholes drilled by Central Ground Water Board reveals that thickness of alluvial deposits increases towards east and southeast. Rajmahal Traps are exposed in Sahebganj district of Bihar, which is to the west and southwest of Malda district. Bore holes drilled in Manikchak and Kaliachak blocks indicate the occurrence of hard rock below 100 m depth. The Older Alluvium occurs in the Barind tract to the east of Mahananda River. It is composed of silt, clay, sand and gravel with ferruginous nodules and calcareous concretions (kankars). Litho-facies variation is a common feature that controls occurrence and movements of groundwater in the 'Barind' tract. In Harishchandrapur and Kaliachak blocks, thickness of top clay layer varies from 3 to 15 m, which is underlain by a layer of fine sand having thickness varying from 10 to 20 m.

A layer of medium to coarse sand (20–60 m thick) underlies the fine sand layer. Thickness of topsoil increases towards north and gets intercalated with silt and fine sand. In Quaternary alluvium, potential aquifers comprising sand, gravel and pebble occurs in the depth range of 15 to 134 m bgl. Subsurface lithological correlation diagram and disposition of aquifers are shown in **Fig.4.1.**



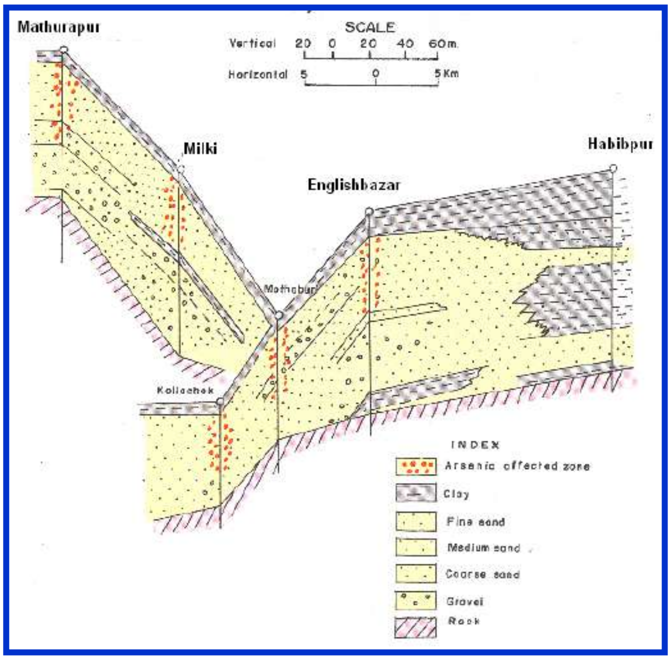


Fig. 4.1 Diagrams showing subsurface lithological correlation, Malda district

4.3 Exploratory Drilling

Central Ground Water Board (CGWB), Eastern Region (ER) has drilled exploratory boreholes and observation wells in 12 locations falling in nine Developmental Blocks of Malda district (as on 31-3-2021), as given below:

Kangsa and Bamongola in Bamongola block, Mandilpur and Maligram in Old Malda block, Nityanandapur in Habibpur block, Amar Singhee and Gobindapur in Ratua-I block, Araidanga in Ratua–II block, Arbara and Kharba Jamuria in Chanchal-I block, Bhaluka in Harischandrapur-II block, Kandar (Kocha) and Pandua in Gazole block, Narendrapur and Malda Sadar Hospital in English Bazar block (as on 31-7-2021). The borehole at Mandilpur encountered gneissic rock at 259.70 m bgl underneath the alluvial formation (Ghosh Dastidar and Adhikari 2008). Groundwater in these tube wells is in general potable and suitable for domestic and irrigational use. Various drilling details of the exploratory drilling (in house) by CGWB, ER are summarized in Table 4.1.

Table 4.1 Details of Exploratory Drilling (In House), Malda district

Sl No	Location	Block	Co-ordinate (in DD)	Drilled Depth (m)	Well Construction Depth (m)	Aquifer	Zones Tapped (mbgl)	Static Water Level (mbgl)	Discharge	Drawdown	Transmissivity, T (m^2/day), Storativity (S)	Chemical Quality	Agency and Year of Construction
1.	Mandilpur (EW)	Old Malda	25.0406 88.1842	280.51	140.0	Older Alluvium	35.76–45.93, 59.05–75.55 104.75 –124.67, 131.23 –137.79	10.57	58.27 lps	5.41 m	296.90 m^2/day	Potable	ETO
2.	Kangsa	Bamongola	25.104 88.371	169.29	157.27	Bore Hole	74.65-110.07, 134.11-137.16	NA	NA	NA	NA	NA	ETO
3.	Nityanan-dapur (EW)	Habibpur	25.0008 88.3599	165.68	139.0	Older Alluvium	50.03–56.63, 102.49–118.99 125.52 –136.74	19.90	13.48 lps	9.84 m	1125.02 m^2/day	Potable	ETO

4.	Bhaluka (DEW)	Harischan-drapur - II	25.2502 87.8927	250.99	244.0	Alluvium	217.0 - 241.0 Cement Sealing 160– 163 m	NA	8.33 lps	NA	NA	Potable	CGWB 2006-07
5.	Bhaluka (IEW)	Harischan-drapur - II	25.2502 87.8927	149.60	146.0	Alluvium	105–127, 130-142 Cement Sealing 80 – 85 m	5.44	46.53 lps	NA	NA	Potable	CGWB 2006-07
6.	Bhaluka (SEW)	Harischan-drapur - II	25.2502 87.8927	61.20	53.0	Alluvium	36.0 - 50.0 clay packing from GL to 10 mbgl	5.51	7.25 lps	1.11 m	1140.74 m^2/day	Potable	CGWB 2006-07
7.	Bhaluka (EW)	Harischan-drapur - II	25.2502 87.8927	223.80	223.0	Alluvium	209 – 221 clay packing from GL to 10 mbgl	NA	NA	NA	NA	Potable	CGWB 2006-07

Sl No	Location	Block	Co-ordinate (in DD)	Drilled Depth (m)	Well Construction Depth (m)	Aquifer	Zones Tapped (mbgl)	Static Water Level (mbgl)	Discharge	Drawdown	Transmissivity, T (m^2/day), Storativity (S)	Chemical Quality	Agency and Year of Construction
8.	Araidanga (EW)	Ratua - II	25.1175 87.9885	145.00	108.0	Alluvium	81 - 105	6.41	35.0 lps	1.33 m	6214.0 m^2/day	Potable	CGWB 2007-08
9.	Araidanga (OW)	Ratua - II	25.1175 87.9885	138.00	108.0	Alluvium	81 - 105	6.98	16.95 lps	NA	7170 m^2/day S = 0.099	Potable	CGWB 2007-08
10.	Malda Sadar Hospital	English Bazar	25.033 88.133	NA	118.87	Alluvium	18.3 – 106.7	NA	NA	NA	NA	Potable	CGWB
11.	Narendrapur (EW)	English Bazar	24.9294 88.1188	156.00	98.0	Older Alluvium	83 – 95 Cement Sealing 67 – 70 m	1.81	33.33 lps	5.33 m	207.81 m^2/day	Potable	CGWB 2007-08
12.	Arbara	Chanchal-I	25.431 88.036	NA	108.0	Younger Alluvium	24-37.5, 51.0-90.0	NA	NA	NA	NA	Potable	CGWB
13.	Kharbari Jhamuria	Chanchal-I	25.423 88.083	NA	120.0	Younger Alluvium	45-57, 60-78, 81-93, 102-112.5	NA	NA	NA	NA	Potable	CGWB
14.	Bamongola High School	Bamongola	25.165 88.341	200.5	127.0	Older Alluvium	112.0-124.0	13.70	11.05 lps	5.95 m	NA	Potable	CGWB 2019-20

Sl No	Location	Block	Co-ordinate (in DD)	Drilled Depth (m)	Well Construction Depth (m)	Aquifer	Zones Tapped (mbgl)	Static Water Level (mbgl)	Discharge	Drawdown	Transmissivity, T (m^2/day), Storativity (S)	Chemical Quality	Agency and Year of Construction
15.	Pandua A.K. High School	Gazole	25.132 88.154	200.0	160.0	Older Alluvium	103-109, 123-132, 148-157	16.50	45.8 lps	NA	NA	Potable	CGWB 2020-21
16.	Gani Khan Chowdhury Institute of Engineering & Technology, Maligram (EW-I)	Old Malda	25.052 88.166	200.0	130.0	Younger Alluvium	103-109, 115-127	NA	NA	NA	NA	NA	CGWB 2020-21
17.	Gani Khan Chowdhury Institute of Engineering & Technology, Maligram (EW-II)	Old Malda	25.052 88.166	200.2	124.0	Younger Alluvium	97-103, 109-121	15.25	45.3 lps	NA	NA	NA	CGWB 2020-21

5. GEOPHYSICAL SURVEY

Surface geophysical survey in the form of Vertical Electric Sounding (VES) was carried out in 20 locations in parts of Habibpur, Bamongola, Manikchak and Ratua-II blocks of Malda district during the AAP: 2005-2006 by Dr. S.K. Adhikari (Ghosh Dastidar and Adhikari 2008). The area covered by VES was bounded by north latitudes 24^0 38' 30" to 25^0 32'08" and east longitudes $87^0$45'50" to 88^0 28'10".

A summary of the geophysical survey in Malda district is given below.

- To delineate potential aquifer in the Barind Tract in Habibpur block, to explore indirectly arsenic-free aquifer in Manikchak block and to detect the presence of inter-trappeans if any, Vertical Electrical Sounding (VES) were completed at 17 locations in Habibpur and Manikchak blocks. Out of these, 4 VES locations were in Manikchak block and remaining 13 were in Habibpur block. Two VES survey were completed in the southern part of Bamongola block and one VES in the southern part of Ratua-II block. The VES field data were interpreted using empirical curves in different orientations. Disposition of various layers, potential zones of groundwater occurrence and presence of inter-trappeans were delineated using Geoelectric Sections and Panel Diagram.
- The maximum current electrode separation (AB) was kept at 800 m to get the maximum depth of investigation. The apparent resistivity was plotted on double log paper and the types of field curves were obtained as A, HA, HK, KQ and H types. All the curves were interpreted by partial curve matching technique and with the help of computer programme 'RESIST' (Ghosh Dastidar and Adhikari, 2008).
- A correlation of the interpreted VES data with available nearby litholog data was made by the authors. The following resistivity range with respect to lithology is given Ghosh Dastidar and Adhikari:

Resistivity range(ohm.m)	**Lithology**
7-160	Topsoil
5-15	Clay
16-30	Fine to medium sand
15-26	Weathered basalt
30-112	Sand, coarse
160-240	Gravel
60-70	Partially weathered basalt
420	Basalt

- With the help of interpreted results, Geoelectric Section for Habibpur block and Panel Diagram for Manikchak block were prepared. It was observed that in general a four to five layered subsurface structure can be identified. These sections are discussed below.

5.1 Geoelectric Section and Panel Diagram

In Habibpur block, falling in Barind tract, a geophysical section trending SW-NE was completed during the Annual Action Plan: 2005-2006. Length of this geophysical section was 18.72 km. Interpretation of the VES data has indicated that top soil of resistivity range varying from 7 to 30 ohm.m was varying in thickness from 1.9 to 4.3 m. The second layer occurring beneath the topsoil is of variable thickness (20 to 62 m) having resistivity varying from 5 to 14 ohm.m. This zone was interpreted as clay layer. The appearance of third layer shows a wavy nature. The resistivity range of 32 to 82 ohm-m indicates that this layer may be composed of coarse grained sand. The depth of this layer varies between 60 and 84.4 m. It was interpreted by Dr. S.K. Adhikari that below this layer, the resistivity falls down to 18 to 20 ohm-m, which was interpreted to be a zone of fine to medium-grained sand. This layer may be extended down to a maximum depth of 200 m. The bottom most layer of resistivity ranging from 40 to 83 ohm-m was presumed to be an aquifer comprising coarse-grained sand. The third and the last layer were interpreted as very good aquifers (Ghosh Dastidar and Adhikari, 2008). Geoelectrical Section in Habibpur block is shown in **Fig. 5.1** whereas Panel Diagram in Manikchak block is shown as **Fig. 5.2.**

Interpretation of VES data in VES sites 4, 5, 6, 7 and 8 has shown occurrence of basaltic rock and alluvium interface having four to five layered structure. Below the topsoil of 1.9 to 4.2 m thickness, a highly resistive layer having resistivity varying from 163 to 240 ohm.m was interpreted at VES site 4 and 5. This may be an aquifer composed of gravel. The third layer of resistivity ranging from 32 to 112 ohm.m was inferred to be an aquifer of coarse sand, whereas the layer having resistivity ranging from 17 to 26 ohm.m was predicted as weathered basalt of Garo-Rajmahal Gap. VES number 7 on the surface is the boundary between two different formations. In the south eastern part, a clay layer of 17 to 75 m thick (within depth range of 30 to 80 m) having low resistivity (3-5 ohm.m) was interpreted below the coarse sand layer. In contrast to this, in the north western part, fresh basalt (resistivity: 420 ohm.m) was detected below the weathered basalt occurring in depth range of 126 to 160 m. The authors have interpreted occurrence of intermediate resistivity zone (70 ohm.m) between two fresh basalt layers. This might be due to occurrence of inter-trappeans of Garo-Rajmahal Gap. It was postulated that the weathered basalt and inter-trappeans may contain some amount of groundwater in the north western part. It was also interpreted from VES survey that the aquifer in third layer in south eastern part of Manikchak block might be the best groundwater bearing zone.

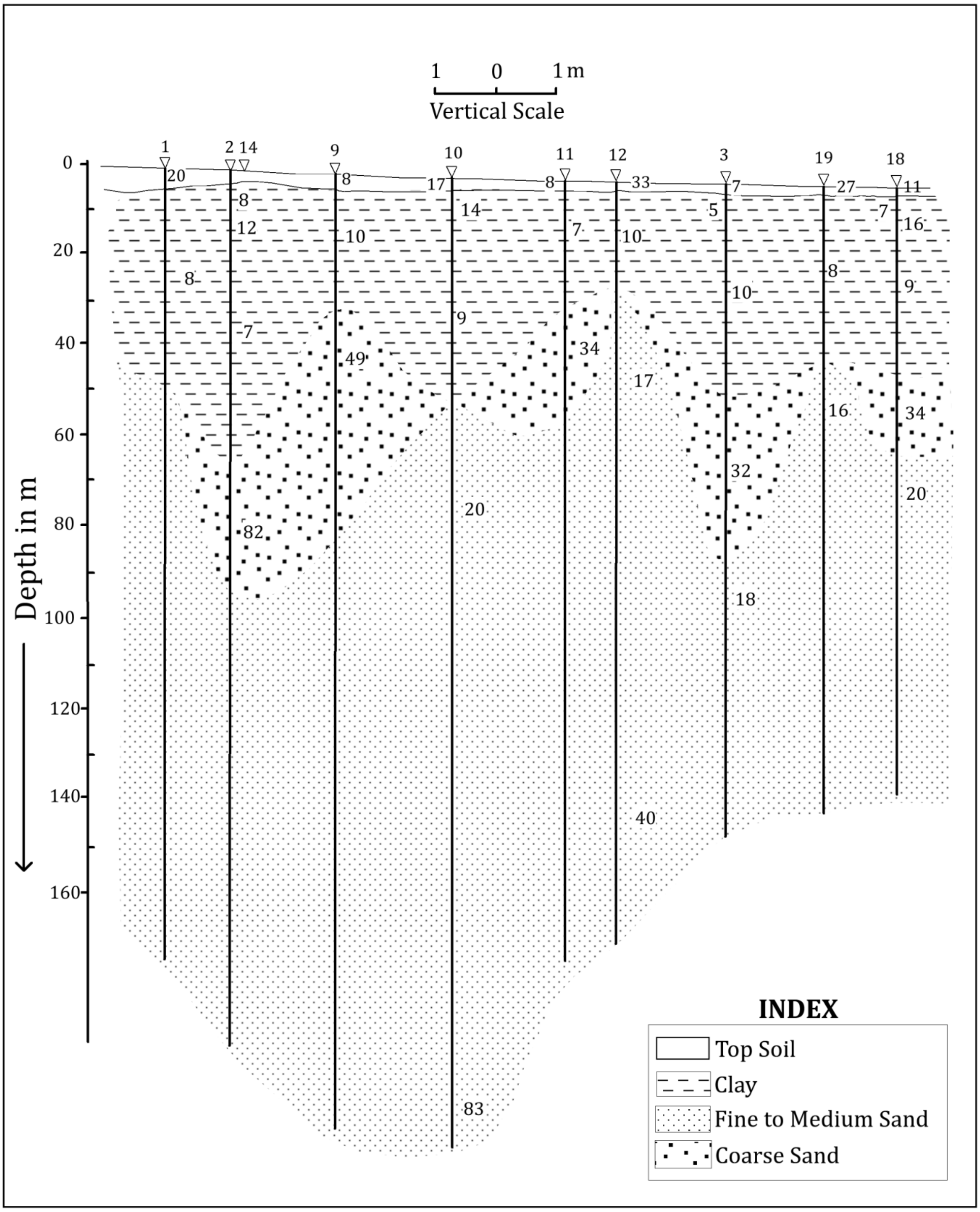


Fig. 5.1 Geoelectric Section, Habibpur block (after Ghosh Dastidar and Adhikari 2008)

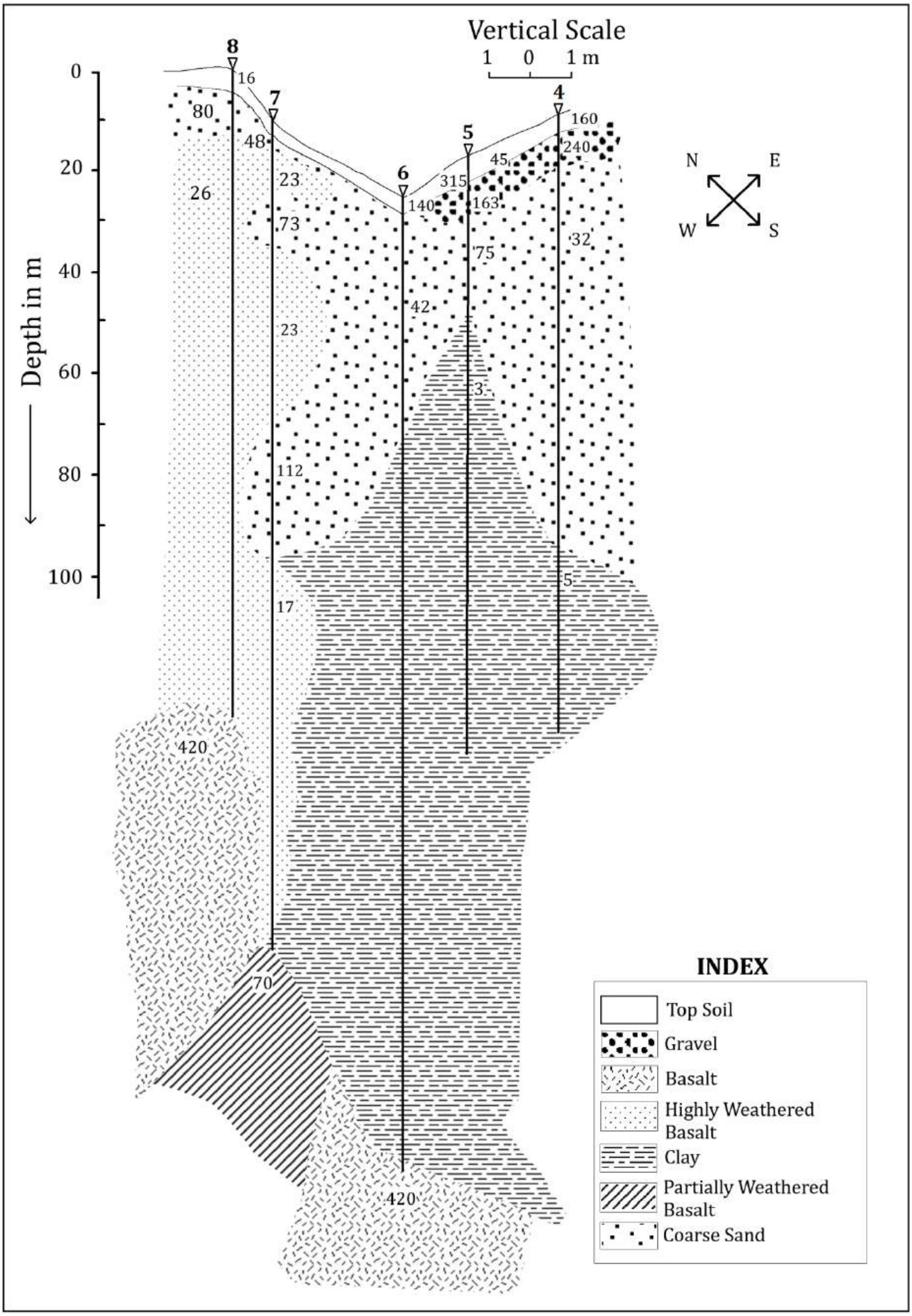


Fig. 5.2 Panel Diagram, Manikchak block (after Ghosh Dastidar and Adhikari 2008)

5.2 Recommendations

Following the analysis of VES data, potential aquifer zones were demarcated in parts of Habibpur and Manikchak blocks. The third layer and the fifth layer in Habibpur block were identified as most suitable for construction of tube wells. In Manikchak block, the authors recognized weathered basalt and coarse sand as potential aquifers for construction of tube wells. Therefore, depending on the extension of this granular zone/ weathered rock the following drilling depths were recommended for 17 VES locations falling in Habibpur and Manikchak blocks (Ghosh Dastidar and Adhikari, 2008).

VES No.	Aquifer thickness (m)	Recommended depth for drilling (m)
1.	Below 50	80
2.	Below 65.8	90
3.	47.9-84.3	90
4.	2.6-84.7	90
5	4.2-30.3	40
6.	2.8-184.8	180
7.	2.2-3.96, 12.06-23.76, 57.76-84.76, below 159.6	170
8.	4.2 –126.6	126
9	Below 29.5	40
10.	Below 200.3	110
11.	Below 28	50
12.	Below 131.8	145
13.	Below 230	250
14.	Below 30.8	50
15.	28.7-76.7	80
16.	Below 48	60
17.	Below 13.5	50

7.3 Conclusion

A total of 20 Vertical Electric Sounding (VES) were carried out during the Annual Action Plan: 2005-06, out of which 17 VES sites were in Habibpur and Manikchak blocks (Ghosh Dastidar and Adhikari, 2008). Based on VES data, two Geoelectrical Section was prepared for Habibpur block and Panel Diagram for Manikchak block. Analysis of VES data indicated that in Habibpur block, two sets of good aquifers are found in the depth range of 26 to 85 m and 130 to 200 m. The depth of these aquifers generally varies from place to place. Interpretation of VES data also revealed that aquifers are made up of coarse-grained sand. In between the two aquifers, another aquifer of much less groundwater potential was inferred. It was inferred that this third aquifer is composed of fine to medium-grained sand, in contrast to the other two aquifers consisting of coarse sand (Ghosh Dastidar and Adhikari, 2008).

In Manikchak block, interpretation of the Panel Diagram reveals a boundary between basalt and alluvial formation at VES site 7. In the north-western part, presence of weathered basalt along with inter-trappeans (of Garo-Rajmahal Gap) was interpreted by the authors. In the south-eastern part of Manikchak block, an aquifer comprising coarse sand and having good groundwater potential was inferred in the depth range of 30 to 80 m (Ghosh Dastidar and Adhikari, 2008).

6. HYDROGEOLOGY

6.1 Regional Hydrogeology

Regional hydrogeological set up of Malda district is characterized by aquifer geometry and aquifer disposition, which are controlled by the spatio-temporal distribution of Quaternary alluvial deposits. The alluvial sediments are categorized into Older alluvium (Aquifer Code: AL-03) and Younger alluvium (Aquifer Code: AL-01). Groundwater generally occurs in two Major Aquifer Systems viz. Aquifer-IA and Aquifer-IB. Aquifer-IA is shallow and occurs under unconfined (rarely semi confined) conditions in the depth range of ~25 m bgl to ~70 m bgl. Aquifer-IB occurs at moderately deep levels, in the depth range of 50 m bgl to ~180 m bgl. The aquifer geometry is governed by variations in grain size distribution of alluvium that has been deposited by major perennial rivers. Coarse sand and gravel having variable texture constitute potential aquifers down to ~90 m bgl in the eastern part and ~150 mbgl in the western part of the district.

Regional hydrogeological framework of Malda district is based on mode of occurrence of groundwater, nature and extent of aquifers and their hydrological, hydrodynamic and hydrochemical properties. During aquifer mapping studies, several promising saturated granular zones are observed to be present in the depth range of 17 to 178 m bgl. Shallow aquifers are in unconfined to semi-confined conditions whereas moderately deep aquifers (especially in Barind tract) occur under confining conditions. A general predominance of sand over clay is observed in the alluvial sequence with occasional discontinuous clay lenses and layers of silty clay. Hydrogeological map of Malda district is shown in **Fig. 6.1.**

6.2. Aquifer System: Although basaltic rocks of Garo-Rajmahal gap and granite gneiss (?) at Mandilpur has been reported at deeper levels (>150 m bgl), details of aquifer disposition of the hard rock aquifer systems (250-400 m) in Malda district is yet to be known, as far as the in-house drilling is concerned. The main water bearing formations (mostly leaky and unconfined aquifers) are Quaternary sediments of Recent (Holocene) and Pleistocene age. Aquifer materials consist of sands of variable grain size (from very fine grained to coarse grained) and gravels. Groundwater occurs in the interstices within the granular zones. The nature of aquifer materials in horizontal and vertical extent is not uniform due to frequent variation in lithofacies in the depositional basin viz. the Ganga Basin.

6.3 Aquifer Geometry: The aquifer geometry of the district is depicted as lithological cross sections and fence diagrams, block wise for all the 15 developmental blocks in Malda district. It is observed that broadly two Aquifer Groups (Aquifer-1A and Aquifer-1B) exist in major parts of Malda district, which is inferred due to development of relatively thick (5-20 m) clay layers between the shallow and the deeper aquifers. However, in parts of Old Malda, Habibpur and Harishchandrapur-II blocks, a single aquifer group (Aquifer-1A) has been developed due to very thin or inconspicuous layers of clay between the promising granular zones of sand and gravel. In the Barind tract, predominance of clay over sand is generally observed. Generally, both vertical and lateral facies variation is commonly observed in the aquifers developed in Malda district.

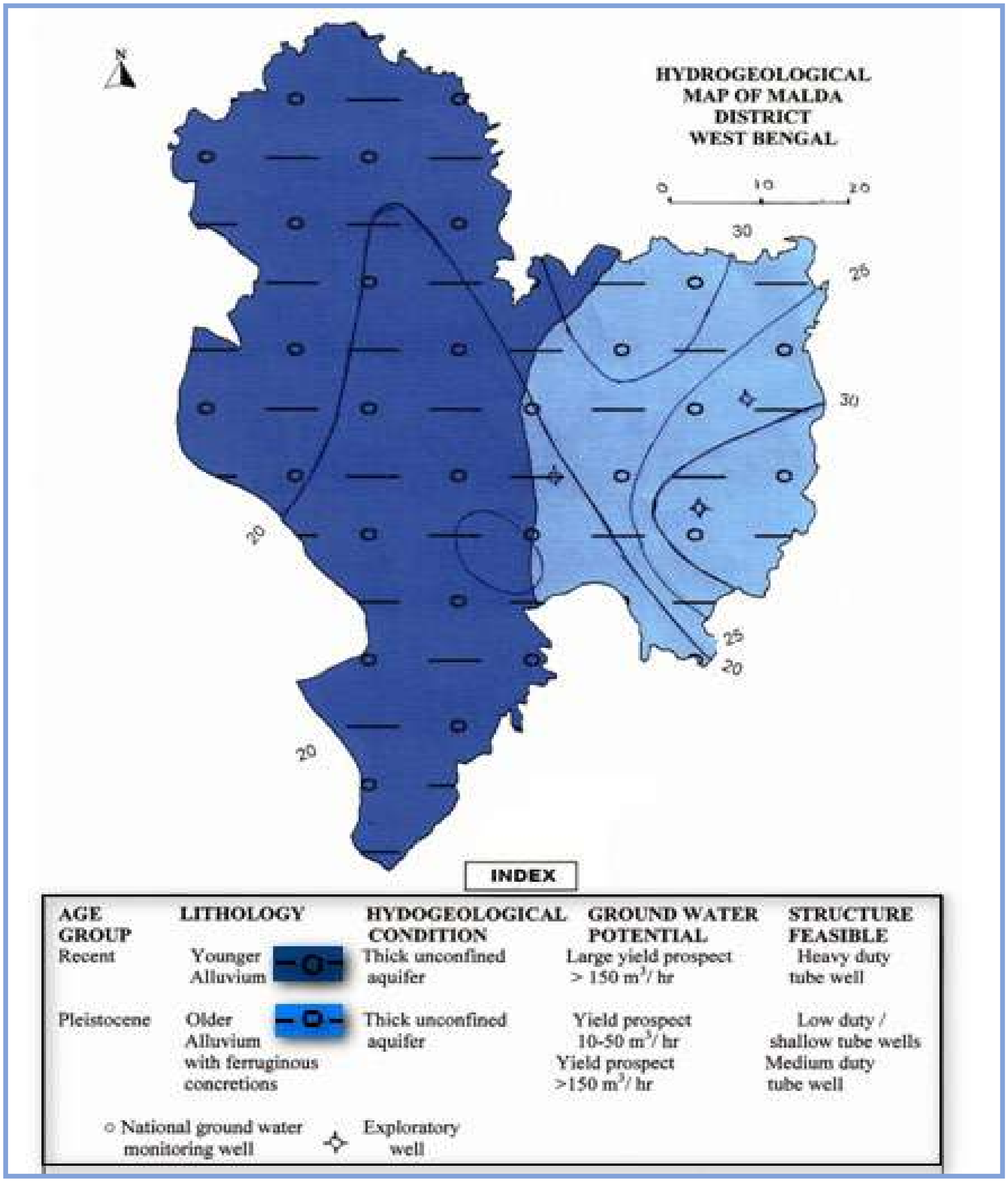


Fig. 6.1 Hydrogeological map of Malda district

6.4 Occurrence, movement and distribution of groundwater

Occurrence and movement of groundwater in unconsolidated formation of the district is mainly controlled by porosity and permeability of the aquifer materials, which changes from place to place. Therefore, depth of occurrence of groundwater also differs from one place to another. The porous formation in the district can be divided into (a) Recent alluvial deposits constituting regionally extensive aquifers and (b) older alluvial deposits constituting discontinuous aquifers. The porous formation covers entire district within the depth range of ~270 m, although in Manikchak block the depth of porous formation is restricted to ~100 m. Groundwater occurs mainly under unconfined condition. However, in some patches particularly in north-western part (Tulsihata-Chanchol section) and in Bamongola block, groundwater occurs under semi-confined condition.

In general, the movement of groundwater is controlled by the hydraulic gradient. The direction of groundwater flow can be visualized from the water table contour map (both pre-monsoon and post-monsoon, 2020). Generally, as depicted from the water table contour map (pre-monsoon), groundwater flows towards the east and south east in the north-western part of Malda district. The disposition of water table contour map shows that in the northern part the district, the Mahananda River is effluent, at least during the pre-monsoon period but become influent in the southern part of the district viz. in English Bazar and Old Malda blocks.

6.5 Aquifer Characteristics and Aquifer Parameters

Hydrogeological details of exploratory wells constructed by Central Ground Water Board (CGWB) and other State Government Agencies in Malda district reveals that yield potential of aquifers increase from east to west and southwest. Aquifer characteristics vary in different hydrogeological units prevailing in the district.

In general, potential aquifers are encountered in the depth zone of 17 to 178 m below ground level. The thickness of the aquifers varies from place to place. As per in-house drilling data of CGWB, Static Water Level (SWL) in the tube wells ranges from 5.44 m bgl at Bhaluka to 19.90 m bgl at Nityanandapur, whereas discharge was found to be varying from 7.25 lps at Bhaluka to 58.27 lps at Mandilpur. Drawdown in the tube wells was ranging from 1.11 m at Bhaluka to 9.84 m at Nityanandapur. Transmissivity of the aquifers, as computed by pumping test, was found to be varying from 207.81 m^2/day at NarendrapurExploratory Well (EW) in English Bazar block to 7170.0 m^2/day at NityanandapurEW in Habibpur block. Storage Co-efficient of the aquifer in the depth range of 81 to 105 m at Araidanga(Ratua-II block) was calculated as 9.9×10^{-2}. This indicates the semi-confined nature of the aquifer in this area.

Quaternary alluvium deposits consisting of sand, silt, clay, and gravel is exposed in the district. In general, groundwater in the shallow aquifers (up to depth of 80 m) occurs under unconfined condition. Such aquifers are developed through shallow, low duty tube wells

(LDTW), which are capable of yielding 25 to 30 m^3/hr of water with 5 HP pump and are mainly used locally for irrigation. Groundwater in the deeper aquifers (below the depth of 100 m and up to the explored depth of 280.51 m) occurs under unconfined to semi-confined condition. Deeper aquifers are developed mainly by electrical submersible pump fitted heavy duty tube wells (HDTW) for use in large-scale drinking water supply and irrigation. These pumps are generally capable of yielding groundwater in the range from ~50 to 100 m^3/hr. A summary table showing block wise hydrogeological data in Malda district (based on CGWB data, data of PHED and SWID, Government of West Bengal), is given in *Table 6.1.*

Table 6.1 Block wise hydrogeological details with drilling depth of tube wells

Sl. No.	Block	Drilled Depth of TWs (m)	Depth range of promising Granular Zones (m bgl)	Discharge (m^3/hr)	Drawdown (m)
1.	English Bazaar	70 - 156	70 - 108	133.44 - 216	3 - 5
2.	Old Malda	96 - 159	30 - 44, 50 - 99, 105 - 125, 130 - 138	135 - 259	7 - 11
3.	Habibpur	67 - 156	21 - 76, 94 - 110	46 - 133.77	5 - 9
4.	Bamongola	155 - 186	98 - 140	10 - 22	6 - 12
5.	Gazole	137 - 179	43 - 56, 76 - 105, 145 - 178	89 - 247	7 - 12
6.	Manikchak	73 - 112	19 - 25, 46 - 75	207.0	3
7.	Chanchal-I	106.0 – 248.47	39 - 57, 60 - 82, 85 - 106, 115 - 149	108 - 122.88	8 - 9
8.	Chanchal-II	106 - 133	28 - 45, 79 - 130	152 - 182.88	6.4
9.	Harishchandrapur-I	96 - 150	32 - 48, 51 - 106, 108 - 118, 121-149	103.5 – 188.0	3.5 - 7.32
10.	Harishchandrapur-II	90 - 251	52 - 146, 217 - 241	152.4 - 182.4	3 - 7.5
11.	Ratua-I	92.0 – 149.6	36 - 50, 72 - 84, 94 - 127, 130 - 142	197.8	3.35
12.	Ratua-II	100 - 118	61 - 91, 100 - 109	180 - 200	2.1 - 4.3
13	Kaliachak – I	45 - 64	30 - 41	180 - 200	2 - 4
14	Kaliachak – II	60 - 85	18 - 80	210 - 215	3.5 - 6
15	Kaliachak – III	49 - 81	17 – 62, 68 - 78	202 - 215	3 - 6

During the NAQUIM study, lithological data (in the form of strata charts) was collected from the Office of the Executive Engineer, Public Health Engineering Department (PHED), Malda Division and also from the Executive Engineer, Arsenic Area Water Supply Scheme, Laxmipur, Malda. On the basis of the data compiled by the author (both In House drilling data and data collected from PHED), lithological logs of 53 exploratory wells/production tube wells has been analyzed for preparation of lithological cross sections, fence/panel diagrams and 3-D block diagrams showing both lithology and stratigraphic successions. Based on this data, fence/panel diagrams for the entire Malda district and 12 developmental blocks (out of 15) were prepared using Rockworks software. Subsurface lithological data for Kaliachak-I, Kaliachak-II and Kaliachak-III blocks were not available due to absence of In House drilling by CGWB in these three blocks and also due to unavailability of bore hole data by the PHED and State Water Investigation Directorate (SWID). Hence, aquifer geometry and correlation between different Aquifer Groups was not possible for these three blocks.

A map showing locations of the 53 exploratory wells/production tube wells in Malda district is shown in *Fig. 6.2.* Based on the subsurface lithological data, two Aquifer Groups were recognized viz. Aquifer-IA and Aquifer-1B. With the help of the data of CGWB and that of PHED, Government of West Bengal, a Fence Diagram for entire Malda district has been prepared, which is shown in *Fig. 6.3.*

6.6 Depth to Water Level

Depth to water level has been analyzed based on the data collected from active Groundwater Monitoring Wells (GWMW) in Malda district. The monitoring was carried out during January, April (pre-monsoon), August (monsoon) and November (post-monsoon) following standard protocol. In the present analysis, the Water Table (WT) was calculated from Depth to Water Level (DTW) data during the years 2019 and 2020. Thematic maps were prepared on the basis of data collected during pre-monsoon and post-monsoon. A perusal of the data indicates that during pre-monsoon 2019, DTW was minimum (1.64 m bgl) at Kadubari dug well in Gazole block whereas maximum pre-monsoon DTW (14.20 m bgl) was recorded at Matoil tube well in Gazole block, followed by 8.32 m bgl at Jalalpur piezometer in Chanchal-II block. During pre-monsoon 2019, the shallowest water level of 0.67 m bgl was recorded at Agampur dug well in Gazole block, followed by 0.69 m bgl at Bholanathpur dug well in English Bazar block. During post-monsoon 2019, the deepest water level of 8.48 m bgl was recorded at Jalalpur piezometer in Chanchal-II block, followed by 7.32 m bgl at Samshi piezometer in Ratua-I block.

During pre-monsoon 2020, the shallowest depth to water level was 0.32 m bgl at Kadubari dug well in Gazole block, followed by 0.38 m bgl at Nalagola in Bamongola block. During post-monsoon 2020, the deepest water level was 5.96 m bgl at Jalalpur piezometer in Chanchal-II block, followed by 5.90 m bgl at Ratua tube well in Ratua-I block. The shallowest depth to water level (post-monsoon 2020) was 0.49 m at Aiho dug well in the boundary of Old Malda and Habibpur blocks, followed by 0.58 m bgl at Bholanathpur dug well in English Bazar block and subsequently by 0.83 m bgl at Adina dug well in Gazole block.

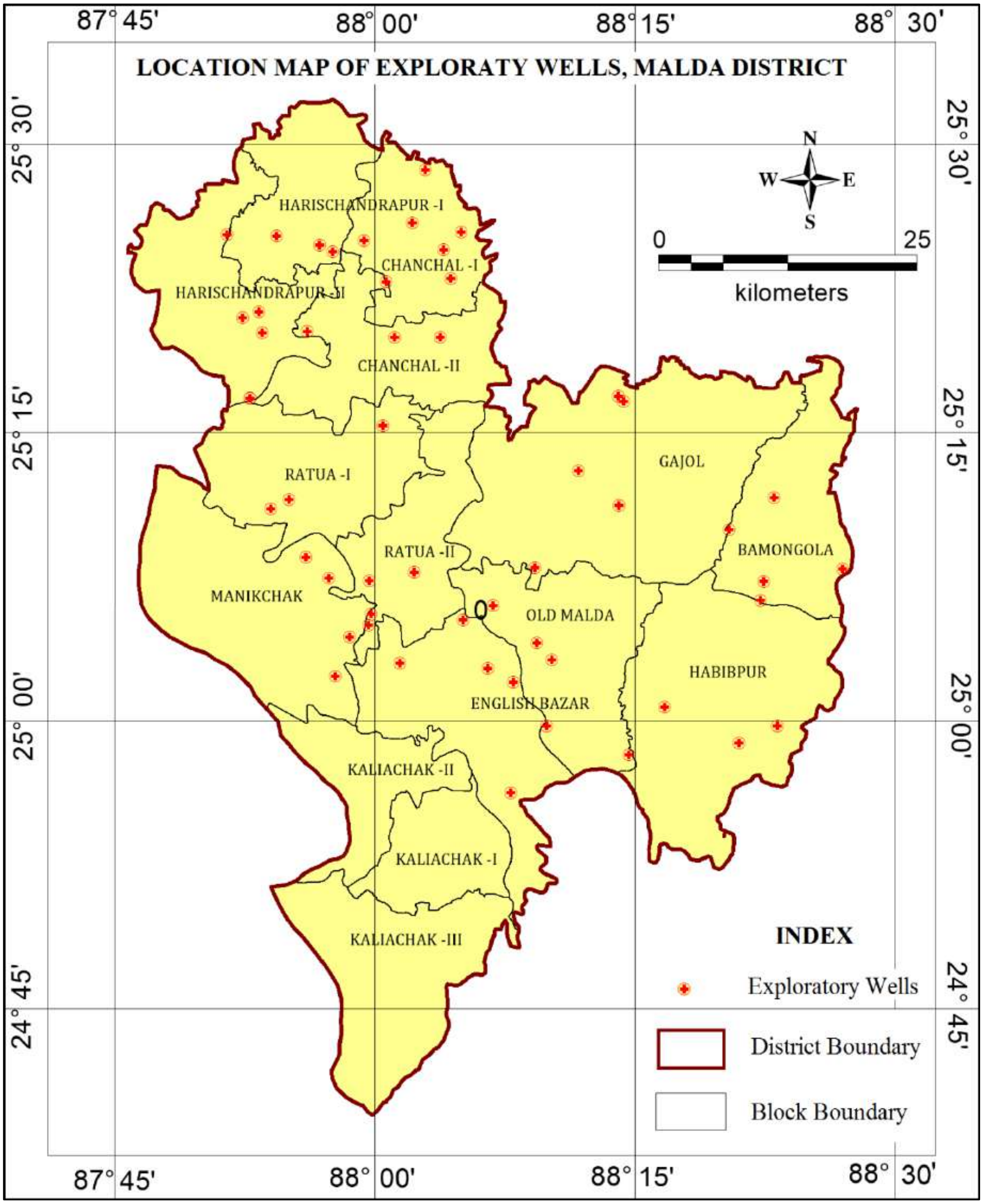


Fig. 6.2 Location map showing exploratory wells and tube wells (both CGWB and PHED, Govt. of West Bengal) in Malda district

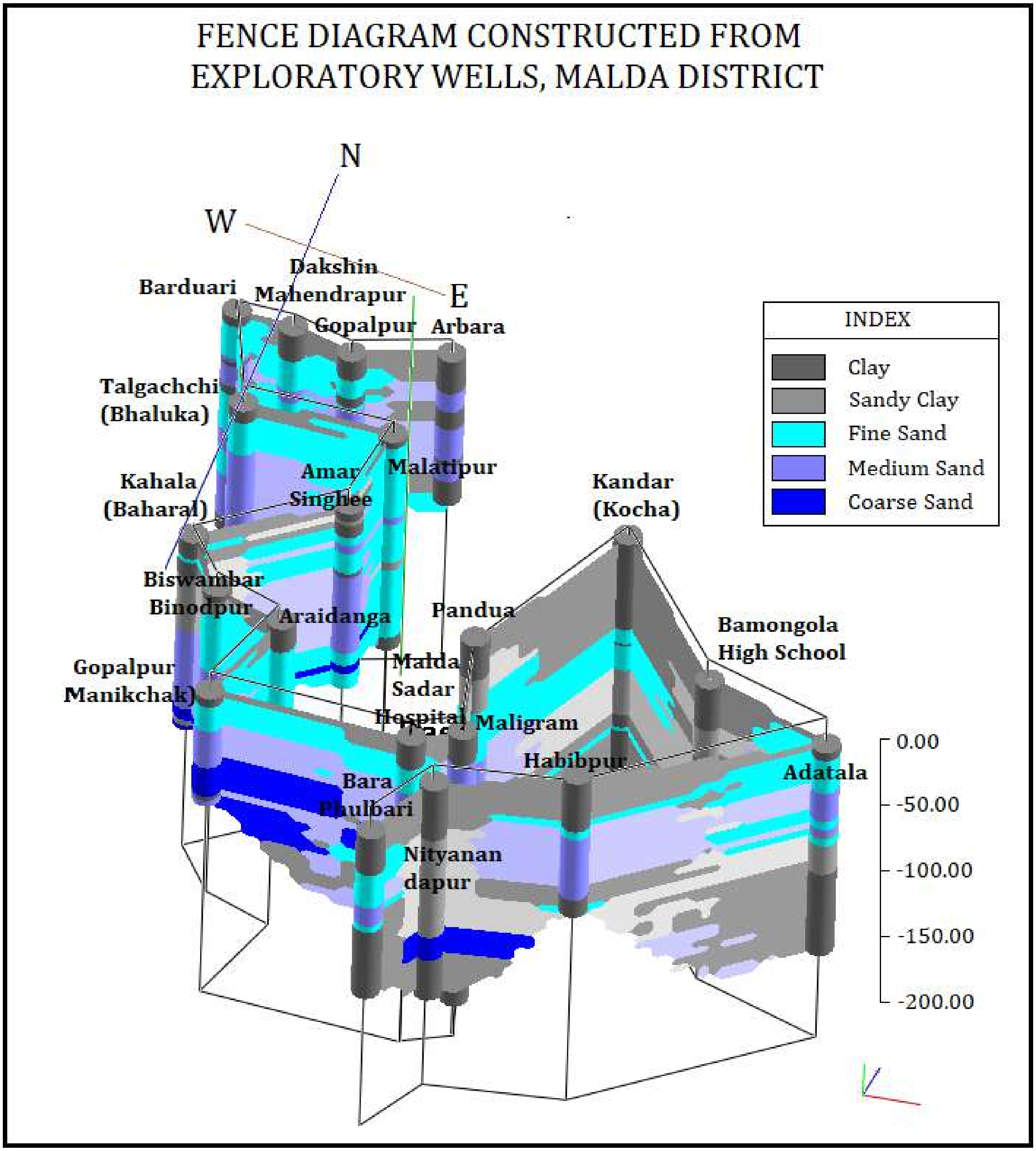


Fig. 6.3 Fence Diagram showing 3-D disposition and correlation of aquifers in Malda district

During pre-monsoon 2020, the shallowest depth to water level was 0.32 m bgl at Kadubari dug well in Gazole block, followed by 0.38 m bgl at Nalagola in Bamongola block. During post-monsoon 2020, the deepest water level was 5.96 m bgl at Jalalpur piezometer in Chanchal-II block, followed by 5.90 m bgl at Ratua tube well in Ratua-I block. The shallowest depth to water level (post-monsoon 2020) was 0.49 m at Aiho dug well in the boundary of Old Malda and Habibpur blocks, followed by 0.58 m bgl at Bholanathpur dug well in English Bazar block and subsequently by 0.83 m bgl at Adina dug well in Gazole block.

For preparation of pre-monsoon and post-monsoon depth to water level (DTW) maps, five categories have been identified viz. 0-5 m, >5 – 10 m, >10 – 15 m, >15 to 20 m and >20 m bgl. The DTW maps for pre-monsoon 2020 and for post-monsoon 2020 are shown in Fig. 6.4 and Fig. 6.5, respectively. A study of these maps clearly indicates the extent of shallow DTW in larger parts of Malda district during the post-monsoon period, as compared to the pre-monsoon period.

A visual analysis of *Fig. 6.4* and *Fig. 6.5* reveals that the highest DTW condition is observed in the south eastern part of Malda district, specifically confined to the south central part of Habibpur block. Deepest water level (>20 m bgl) is also observed as a small patch in the south western part of Bamongola block, both during the pre-monsoon and post-monsoon period in the year 2020. Relatively shallow depth to water level (0-5 m bgl and >5-10 m bgl) was found to occur extensively in the north western, central, western, south central and southern parts of Malda district. Intermediate i.e. moderately deep water level (>10-15 m bgl and >15-20 mbgl) condition was observed in east central and south eastern parts of the district, falling in Gazole, Bamongola and Habibpur blocks. Therefore, it may be concluded that the Older Alluvium (Barind tract) is characterized by deeper water levels as compared to the Younger Alluvium.

Apart from the in house monitoring data, depth to water level and lithological log of fifty five wells (including piezometer and dug well) was collected from State Water Investigation Directorate (SWID), Water Resources Investigation and Development Directorate (WRIDD), Government of West Bengal. The data of 39 Piezometers, fitted with Digital Water Level Recorder (DWLR) system is available for 39 Piezometers and Dug Wells. The relevant data on location, drilled depth, depth of zones tapped and depth to water level (DTW) for pre-monsoon (April 2020) and post-monsoon (November 2020), which was collected from SWID, Malda Division, is given in **Table 6.2.**

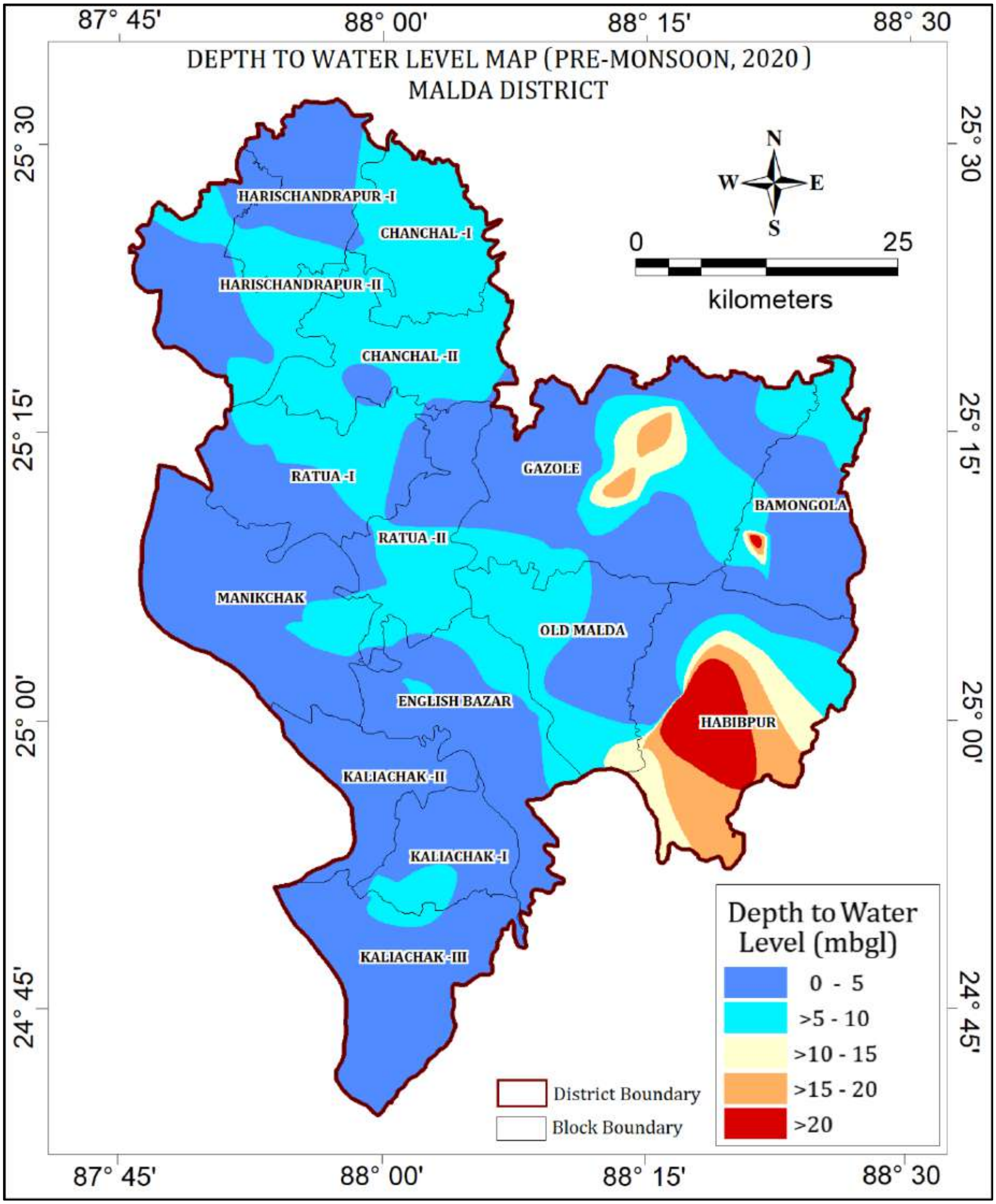


Fig. 6.4 Depth to Water Level map, Pre-monsoon 2020, Malda district

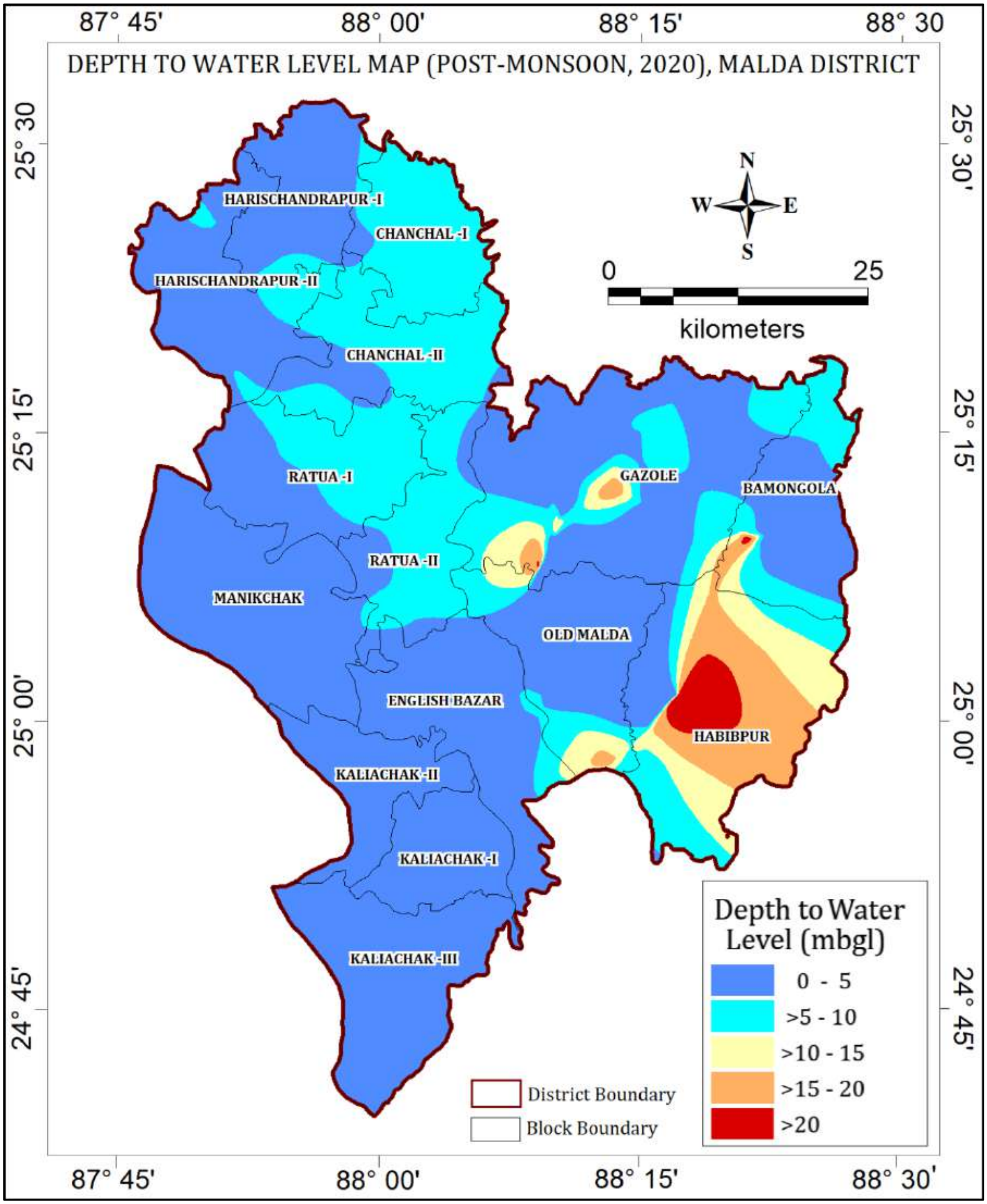


Fig. 6.5 Depth to Water Level map, Post-monsoon 2020, Malda district

Table 6.2 Depth to Water Level and other relevant data of Piezometers installed by State Water Investigation Directorate (SWID), Malda Division

Sl. No.	Hydrograph Station No.	Name of Block	Location	Type of Well	Depth (m)	Zone (m)	Latitude	Longitude	DTW (April 2020)	DTW (Nov. 2020)	Remarks
1	1	Harishchandrapur-I	BDO Office	Piezometer (PZ)	55.57	49.48-53.23	25.4132	87.8855	5.84	4.20	DWLR
2	2	Harishchandrapur-I	Tulshitola Irri. Bungalow	PZ	65.34	58.24-62.54	25.4542	87.9076	3.74	4.49	DWLR
3	50	Harishchandrapur-II	Datian MNGD Primary School (Road from Barduary Bazar)	PZ	NA	NA	25.4353	87.8345	5.26	5.04	DWLR
4	51	Harishchandrapur-II	Daulatpur GPO	PZ	NA	NA	25.3706	87.9139	7.96	6.24	DWLR
5	52	Harishchandrapur-II	JagannathpurPurbapara Primary School, behind Fatepur village	PZ	NA	NA	25.3230	87.8891	4.82	3.01	DWLR
6	4	Chanchal-I	Chanchal BSF Camp	PZ	55.81	50.63-54.29	25.3867	88.0095	9.08	6.34	DWLR
7	5	Chanchal-I	Kharba APO	PZ	45.22	38.42-42.42	25.4227	88.0785	6.87	6.76	NA
8	30	Chanchal-I	Bhagabanpur APO	PZ	67.80	NA	25.4414	88.0425	6.44	6.37	DWLR

9	6	Chanchal-II	Malatipur APO	PZ	42.41	NA	25.3292	88.0191	9.35	8.29	DWLR
10	7	Chanchal-II	Kajaldighi Primary School, Samsi	Dug Well	78.99	NA	25.2874	88.0006	3.41	3.30	P-tube defunct.
11	37	Chanchal-II	Jalalpur APO	PZ	41.97	NA	25.3322	88.0640	8.33	8.31	NA
12	8	Ratua-I	Ratua Mango Research Farm	PZ	NA	NA	25.2170	87.9249	6.05	0	DWLR
13	9	Ratua-I	Bhaluka Irrigation Bungalow	PZ	59.54	53.04-57.04	25.2785	87.8803	5.90	5.57	DWLR
14	34	Ratua-I	Vado APO	PZ	44.28	38.49-42.15	25.2438	87.9620	8.76	8.64	DWLR
15	10	Ratua-II	Gobarjana APO	PZ	49.22	43.78-47.44	25.1058	88.0063	6.66	5.67	DWLR
16	38	Ratua-II	Sripur APO	PZ	54.16	NA	25.2189	88.0641	10.59	0	DWLR
17	35	Manikchak	Kalindri High School	PZ	60.26	NA	25.0621	87.9629	5.58	4.78	DWLR
18	NA	Kaliachak-I	Kaliachak-II GPO (NimnaBuniyadi Vidyalaya, Baliadanga)	PZ	NA	NA	24.8626	88.0181	3.40	3.62	DWLR
19	NA	Kaliachak-I	Jaluabathan GPO, Mallikpara	PZ	NA	NA	24.8626	88.0944	4.29	0	DWLR
20	NA	Kaliachak-I	Kaliachak-I BDO Office,	PZ	NA	NA	24.8717	88.0313	3.67	0	N.A.

			Baliadanga								
21	N.A.	Kaliachak-I	Sujapur GPO, ChotoSujapur	PZ	NA	NA	24.9192	88.0931	3.43	2.84	DWLR
22	N.A.	Kaliachak-I	Jalalpur GPO, Sherpur	PZ	NA	NA	24.8969	88.0660	2.74	3.06	DWLR
23	N.A.	Kaliachak-I	Alinagar GPO (Baro Masjid),Nurnag ar	PZ	NA	NA	24.8855	87.9936	3.72	3.67	NA
24	16	Kaliachak-II	Mothabari Health Centre	PZ	43.33	NA	24.9334	88.0357	3.29	4.27	DWLR
25	17	Kaliachak-II	Muthabari High Sch.	PZ	48.82	43.24-47.31	24.9296	88.0363	4.28	2.66	DWLR
26	19	Kaliachak-III	Birnagar High School/ Panchayat Office	PZ	61.34	54.99-58.99	24.8391	87.9512	4.35	0	DWLR
27	20	Old Malda	Malda P. W. D. Godown	PZ	49.38	44.17-47.38	25.0163	88.1478	9.16	9.68	DWLR
28	21	Old Malda	Mandilpur B. S. F. Camp	PZ	95.03	87.86-91.86	25.0661	88.1451	0	7.34	DWLR
29	39	Old Malda	Muchia A.P.O.	PZ	63.59	NA	24.9654	88.2225	15.46	16.18	DWLR
30	22	English Bazar	Englishbazar B. S. F. Camp	PZ	43.24	38.03-41.69	24.9803	88.1419	5.80	0	DWLR
31	33	English Bazar	Phulbaria A.P.O.	PZ	57.15	NA	25.0438	88.0316	7.56	0	DWLR
32	NA	English Bazar	Agro Industries Complex	PZ	NA	NA	24.9874	88.1402	7.37	0	DWLR
33	24N	Gazole	Near Gazole	Dug Well	NA	NA	25.2203	88.1940	1.16	1.02	NA

			Block Seed Farm								
34	29	Gazole	Balarampur A.K. Kendra	PZ	69.23	62.03-66.05	25.2003	88.2272	17.23	17.06	N.A.
35	NA	Gazole	Deotala GPO (21 mile)	PZ	N.A.	NA	25.2645	88.2722	16.10	10.12	DWLR
36	NA	Gazole	Pandua GPO, Alampur, Adina	PZ	N.A.	NA	25.1676	88.1720	3.39	16.26	DWLR
37	25	Bamongola	Ramkrishnapur B.S.F. Camp	PZ	99.83	92.87-99.81	25.1582	88.3543	25.37	22.47	DWLR
38	28 New	Bamongola	Pakuya APO	PZ	NA	NA	25.1255	88.3673	8.42	0	DWLR
39	27	Habibpur	Block Seed Farm,Habibpur	PZ	63.80	56.44-60.47	24.9853	88.2556	16.51	13.21	DWLR

Index: DWLR – Digital Water Level Recorder, NA – Not Available, APO – Anchal Panchayat Office, GPO – Gram Panchayat Office, BDO – Block Development Officer, BSF – Border Security Force

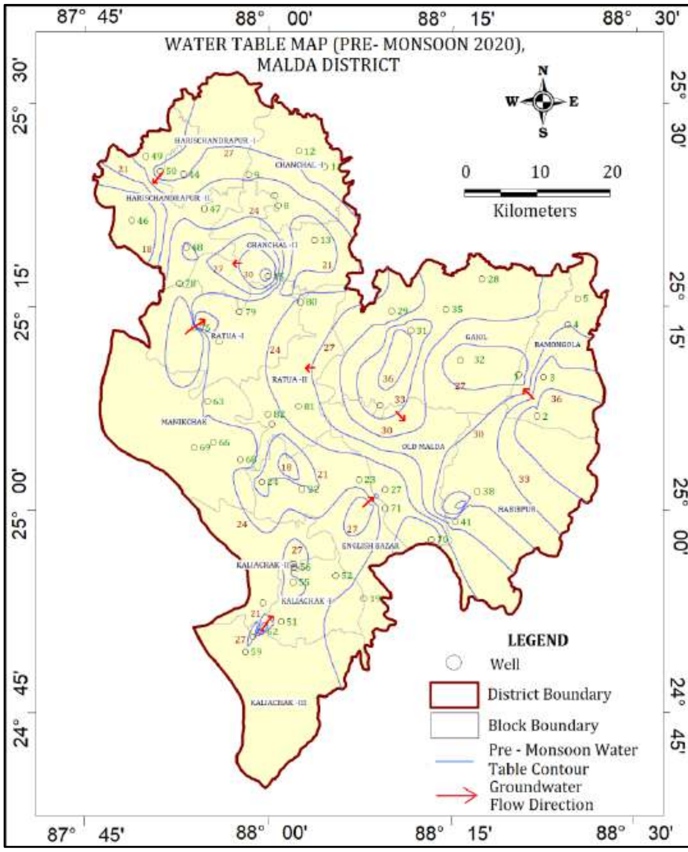
Analysis of depth to water level data of SWID, Malda Division reveals that during pre-monsoon 2020, the shallowest depth to water level (DTW) of 1.16 m bglwas recorded in a dug well near Gazole Block Seed Farm, which was followed by 2.74 m bgl in a piezometer fitted with DWLR at Sherpur, under the Jalalpur Gram Panchayat Office (GPO) in Chanchal-II block. The deepest DTW of 25.37 m bgl was observed at Ramkrishnapur B.S.F. piezometer in Bamongola block, which is followed by 17.23 m bgl at Balarampur Krishak Kendra in Gazole block. During post-monsoon 2020, the shallowest DTW of 1.02 m bgl was observed near Gazole Block Seed Farm, followed by 2.66 m bgl at Mothabari High School in Kalaichak-II block. The deepest water level of 22.47 m bgl was recorded again at Ramkrishnapur B.S.F. piezometer in Bamongola block, followed by 17.06 m bgl in the piezometer at Balarampur Krishak Kendra in Gazole block.

A perusal of the data reveals that deepest water level (>20 m bgl) was observed in the eastern part of Gazole block and in the western part of Bamongola block during the pre-monsoon period, 2020. Deeper water level condition (>15 to 20 m bgl) was observed in the south eastern part of Old Malda block and in the south central and southern parts of Habibpur block. Apart from this, major parts of Malda district are characterized by shallow water level (0 to 15 m) in pre-monsoon 2020. In post-monsoon 2020, deepest water level (>20 m bgl) was observed in south eastern part of Gazole block, northern and north eastern parts of Habibpur block and in major parts of Bamongola block, except its northern part. Shallowest water level (0-5 m bgl) was observed in southern part of Manikchak block, western part of English Bazar block, almost throughout the entire area in Kaliachak-I, Kaliachak-II and Kaliachak-III blocks, in north western part of Malda district falling in Harishchandrapur-I, Harishchandrapur-II blocks and within a small area in the north western part of Gazole block.

6.7 Water table contours and groundwater flow direction

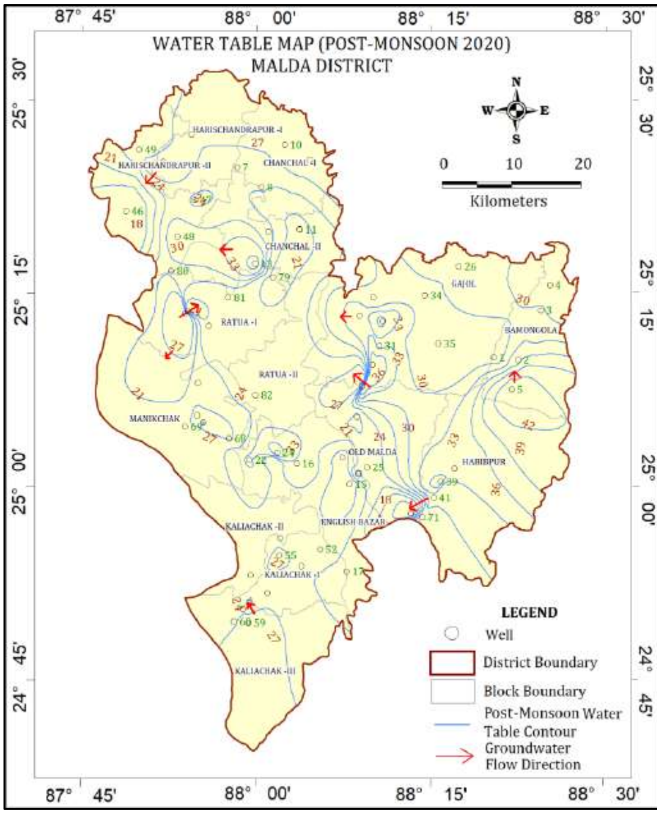
During the present study, elevations of the monitoring wells and key observation wells (KOW) were measured in field using portable GPS receiver. The GPS data was subsequently transferred into desktop platform using Garmin Mapbasic software. With the help of elevation and depth to water level data, reduced level of each of the monitoring wells was calculated. The elevation of the Water Table data was used for preparation of water table contour maps, for the entire district as well as for the 15 developmental blocks.

During preparation of these maps, a uniform contour interval (CI) of 3 m was used for pre-monsoon and post-monsoon, 2020 for Malda district as a whole. The regional groundwater flow direction was interpreted with the 3 m CI. However, while preparing the water table contour maps at block level, the CI was kept at 2 m so as to have sufficient number of WT contours for determination of local groundwater flow direction. The Water Table Contour Maps of Malda district for pre-monsoon and post-monsoon 2020, are shown in Fig. 5.8 and Fig. 5.9, respectively.



Sl_No	Location	Sl_No	Location
1	Bamongola	46	Mianhat (Janaki Nagar)
2	Makuli	47	Daulatpur Gram Panchayat Office (GPO)
3	Paikpara	48	Jagannathpur Primary School
4	Charakdanga	49	Datian Primary School
5	Nalagola	50	Barduari EW
8	Paharpur	51	Baliadanga Lower Buniadi School
9	Kanua (Opposite B. Ed. College)	52	Sujapur GPO, Choto Sujapur
10	Block Seed Farm, Chanchal	54	Alinagar GPO, Nurnagar Mosque
11	Kharba	55	Puratan Pataldanga
12	Paschim Bhagabanpur	56	Mothabari (High School)
13	Jalalpur	57	Muthabari Health Centre
14	Malatipur	58	Muthabari High School
15	Kajaldighi Primary School	59	17 Mile
16	Jalalpur	60	Mahajantala
19	Bholanathpur	62	Pagla Bridge
22	Choto Mohanpara-II	63	Begamganj
23	Nimasarai	66	Mohana-III
24	Milki Primary Health Centre (PHC)	68	Kalindri High School
27	Mangalbari (Behula Bridge)	69	Manikchak (near SBI)
28	Deotala	70	Muchia
29	Mashaldighi	71	Sahapur
30	Pandua	74	Ratua (TW)
31	Gajol	75	Debipur
32	Agampur	78	Bhaluka Irrigation Bungalow
35	Panchamukhi	79	Bhado
38	Habibpur	80	Sripur
40	Haldarpara (Habibpur)	81	Peerganj
41	Block Seed Farm, Habibpur	82	Pukuriya More
42	Tulsihata	83	Gobarjana
44	BDO Office, Harishchandrapur		

Fig. 6.6 Water Table Map showing regional groundwater flow direction, pre-monsoon 2020, Malda district



SL_NO	LOCATION	SL_NO	LOCATION
1	Bamongola	43	IOL Petrol Pump, Harishchandrapur
2	Paikpara	44	BDO Office, Harishchandrapur
3	Charakdanga	46	Mianhat (Janaki Nagar)
4	Nalagola	47	Daulatpur Gram Panchayat Office (GPO)
5	Pakua Panchayat Office	48	Jagannathpur Primary School
7	Kanua (Opposite B. Ed. College)	49	Datian Primary School
8	Block Seed Farm, Chanchal	50	Barduari EW
9	Kharba	51	Baliadanga Lower Buniadi School
10	Paschim Bhagabanpur	52	Sujapur GPO, Choto Sujapur
11	Jalalpur	53	Jalalpur GPO, Sherpur
12	Malatipur	54	Alinagar GPO, Nurnagar Mosque
13	Kajaldighi Primary School	55	Puratan Pataldanga
14	Jalalpur	57	Muthabari Health Centre
15	Malda Town	59	Doriapur
16	Bottally	60	17 Mile
17	Bholanathpur	61	16 Mile
21	Nimasarai	62	Pagla Bridge
22	Milki Primary Health Centre (PHC)	63	Begamganj
24	Phulbaria	65	Mohana-II
25	Mangalbari (Behula Bridge)	66	Mohana-III
26	Deotala	68	Kalindri High School
27	Mashaldighi	69	Manikchak (near SBI)
28	Pandua	70	Jadupur
30	Matoil	71	Aiho
31	Ghaksole	73	PWD Godown, Malda Town
32	Adina	74	Muchia Panchayat Office
33	Kadubari	75	Ratua
34	Panchamukhi	76	Ratua (TW)
35	Agampur	77	Debipur
36	Pandua (A. K. High School)	78	Debipur
38	Habibpur	79	Bhagabanpur
39	Kokabeni	80	Bhaluka Irrigation Bungalow
40	Haldarpara (Habibpur)	81	Bhado
41	Block Seed Farm, Habibpur	82	Pukuriya More
42	Tulsihata		

Fig. 6.7 Water Table Map showing regional groundwater flow direction, post-monsoon 2020, Malda district

6.8 Seasonal Fluctuation in groundwater level

Using the depth to water level (DTW) data of pre-monsoon and post-monsoon 2020, the seasonal fluctuation in groundwater level has been calculated for 72 wells including ground water monitoring wells (GWMW) of CGWB and piezometers of State Water Investigation Directorate (SWID), Government of West Bengal. The seasonal fluctuation (pre-monsoon versus post-monsoon 2020) data is given in **Table 6.3.**

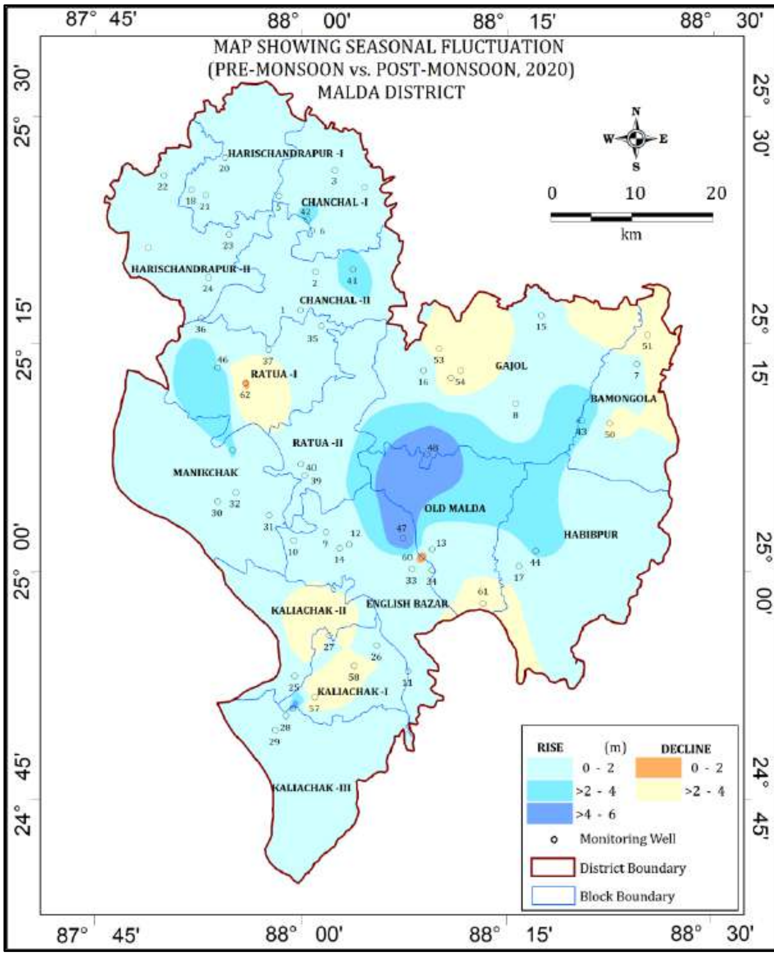
A perusal of data in the table reveals that, out of total 72 wells, 59 wells have shown seasonal rise in water level whereas only 13 wells have shown seasonal decline. Among the 59 wells showing seasonal rise, majority of wells (46 out of 59, 63.89% of total) have shown rise in the range 0-2 m, 10 wells (out of 59, 16.95%) have shown seasonal rise from >2 to 4 m and only 3 wells (out of 59, 5.08% of total) have shown seasonal rise ranging from >4 to 6 m. A total of 13 wells out of 72 wells (18.06% of total number) have shown seasonal decline ranging from 0 to 2 m, whereas only one monitoring well at Ratua has recorded seasonal decline in the range >2 – 4 m during the year 2020. The map showing seasonal fluctuation in groundwater level in Malda district is shown in **Fig. 6.8.**

Table 6.3 Seasonal fluctuation in groundwater level, Malda district

SL NO.	BLOCK	WELL NO.	LOCATION	Depth to Water Level (Pre-monsoon 2020)	Depth to Water Level (Pre-monsoon 2020)	Fluctuation (m)
1	CHANCHAL-II	WBMDNA-15	Jalalpur	8.33	8.31	0.02
2	CHANCHAL-II	WBMDNA-14	Kajaldighi Primary School	3.41	3.30	0.11
3	CHANCHAL-II	WBMDNA-13	Malatipur	9.35	8.29	1.06
4	CHANCHAL-I	WBMDNA-12	Paschim Bhagabanpur	6.44	6.37	0.07
5	CHANCHAL-I	WBMDNA-11	Kharba	6.87	6.76	0.11
6	CHANCHAL-I	WBMDNA-36	Kanua (Opposite B. Ed. College)	4.86	4.42	0.44
7	CHANCHAL-I	WBMDNA-35	Paharpur	7.12	6.44	0.68
8	BAMONGOLA	WBMD87	Charakdanga	1.01	0.80	0.21
9	BAMONGOLA	WBMD104	Agampur	3.77	2.64	1.13
10	ENGLISH BAZAR	WBMDNA-41	Phulbaria	4.28	4.13	0.15
11	ENGLISH BAZAR	WBMDNA-38	Milki Primary Health Centre	2.57	2.31	0.26
12	ENGLISH BAZAR	WBMD12	Bholanathpur	0.87	0.58	0.29
13	ENGLISH BAZAR	WBMDNA-1	Bholanathpur	3.41	3.04	0.37
14	ENGLISH BAZAR	WBMD09B	Bottally	2.22	1.54	0.68
15	ENGLISH BAZAR	WBMDNA-42	Mangalbari (Behula Bridge)	4.90	4.21	0.69
16	ENGLISH BAZAR	WBMD63	ChotoMohanpara-I	5.25	3.48	1.77
17	ENGLISH BAZAR	WBMD64	ChotoMohanpara-II	5.59	3.72	1.87
18	GAZOLE	WBMDNA-44	Deotala (Near Post Office)	3.06	2.54	0.52
19	GAZOLE	WBMD73	Matoil	2.49	1.75	0.74
20	HABIBPUR	WBMD79	Kokabeni	1.94	1.37	0.57
21	HARISHCHANDRAPUR-I	WBMDNA-34	IOL Petrol Pump,	5.07	4.82	0.25

			Harishchandrapur			
22	HARISHCHANDRAPUR-I	WBMDNA-37	Mianhat (Janaki Nagar)	3.81	3.27	0.54
23	HARISHCHANDRAPUR-I	WBMD96	Tulsihata	3.83	2.35	1.48
24	HARISHCHANDRAPUR-I	WBMDNA-5	BDO Office, Harishchandrapur	5.84	4.20	1.64
25	HARISHCHANDRAPUR-II	WBMDNA-9	Datian Primary School	5.26	5.04	0.22
26	HARISHCHANDRAPUR-II	WBMDNA-7	Daulatpur Gram Panchayat Office (GPO)	7.96	6.24	1.72
27	HARISHCHANDRAPUR-II	WBMDNA-8	Jagannathpur Primary School	4.82	3.01	1.81
28	KALIACHAK-I	WBMDNA-23	Alinagar GPO, Nurnagar Mosque	3.72	3.67	0.05
29	KALIACHAK-I	WBMDNA-21	Sujapur GPO, ChotoSujapur	3.43	2.84	0.59
30	KALIACHAK-II	WBMD61	PuratanPataldanga	2.91	2.76	0.15
31	KALIACHAK-II	WBMD102	Mothabari (High School)	4.08	3.92	0.16
32	KALIACHAK-II	WBMDNA-25	Muthabari High School	4.28	2.66	1.62
33	KALIACHAK-III	WBMD49	16 Mile	2.46	2.15	0.31
34	KALIACHAK-III	WBMD47	17 Mile	2.51	2.10	0.41
35	MANIKCHAK	WBMD-02A	Manikchak (near SBI)	4.82	4.58	0.24
36	MANIKCHAK	WBMD67	Mohana-II	4.58	2.88	1.70
37	MANIKCHAK	WBMDNA-19	Kalindri High School	5.58	4.78	0.80
38	MANIKCHAK	WBMD66	Mohana-I	4.07	2.75	1.32
39	OLD MALDA	WBMD14	Malda Town	1.54	0.94	0.60
40	OLD MALDA	WBMDNA-32	Sahapur	6.71	5.46	1.25
41	RATUA-I	WBMDNA-35	Bhagabanpur	7.33	6.58	0.75
42	RATUA-I	WBMDNA-16	Bhaluka Irrigation Bungalow	5.90	5.57	0.33
43	RATUA-I	WBMDNA-17	Bhado	8.76	8.64	0.12
44	RATUA-I	WBMDNA-40	Debipur	5.17	4.90	0.27
45	RATUA-II	WBMDNA-18	Gobarjana	6.66	5.67	0.99
46	RATUA-II	WBMDNA-39	Pukuriya More	4.92	4.68	0.24
47	CHANCHAL-II	WBMD95	Jalalpur	8.32	5.96	2.36

48	CHANCHAL-I	WBMDNA-10	Block Seed Farm, Chanchal	9.08	6.34	2.74
49	BAMONGOLA	WBMD07C	Bamongola	5.18	2.21	2.97
50	ENGLISH BAZAR	WBMD29	Milki	5.10	2.04	3.06
51	HABIBPUR	WBMD04	Habibpur	3.38	1.22	2.16
52	HABIBPUR	WBMD04A	Haldarpara (Habibpur)	3.38	0.47	2.91
53	HABIBPUR	WBMDNA-2	Block Seed Farm, Habibpur	16.51	13.21	3.30
54	MANIKCHAK	WBMD31B	Begamganj	4.73	2.67	2.06
55	MANIKCHAK	WBMD69	Mohana-IV	5.62	2.74	2.88
56	RATUA-I	WBMD37B	Debipur	4.73	1.01	3.72
57	ENGLISH BAZAR	WBMD01A	Nimasarai	7.34	2.10	5.24
58	GAZOLE	WBMD75	Pandua	6.50	1.49	5.01
59	KALIACHAK-III	WBMD89	Pagla Bridge	6.13	1.13	5.00
60	BAMONGOLA	WBMD86	Paikpara	1.88	1.95	-0.07
61	BAMONGOLA	WBMD88	Nalagola	0.38	1.37	-0.99
62	GAZOLE	WBMD06	Deotala	0.77	1.09	-0.32
63	GAZOLE	WBMD15	Mashaldighi	2.03	2.43	-0.40
64	GAZOLE	WBMD22	Gazole	0.32	1.31	-0.99
65	GAZOLE	WBMD93	Kadubari	0.32	1.24	-0.92
66	HARISHCHANDRAPUR-I	WBMDNA-6	Tulsihata Irrigation Bungalow	3.74	4.49	-0.75
67	KALIACHAK-I	WBMDNA-20	Baliadanga Lower Buniadi School	3.40	3.62	-0.22
68	KALIACHAK-I	WBMDNA-22	Jalalpur GPO, Sherpur	2.74	3.06	-0.32
69	KALIACHAK-II	WBMDNA-24	Muthabari Health Centre	3.29	4.27	-0.98
70	OLD MALDA	WBMDNA-26	PWD Godown, Malda Town	9.16	9.68	-0.52
71	OLD MALDA	WBMDNA-27	Muchia Panchayat Office	15.46	16.18	-0.72
72	RATUA-I	WBMD42	Ratua (Tube Well)	3.83	5.90	-2.07



SL NO	LOCATION	SL NO	LOCATION
1	Kajaldighi Primary School	30	Manikchak (near SBI)
2	Malatipur	31	Kalindri High School
3	Paschim Bhagabanpur	32	Mohana-I
4	Kharba	33	Malda Town
5	Kanua (Opposite B. Ed. College)	34	Sahapur
6	Paharpur	35	Bhagabanpur
7	Charakdanga	36	Bhaluka Irrigation Bungalow
8	Agampur	37	Bhado
9	Phulbaria	39	Gobarjana
10	Milki Primary Health Centre (PHC)	40	Pukuriya More
11	Bholanathpur	41	Jalalpur
12	Bottaly	42	Block Seed Farm, Chanchal
13	Mangalbari (Behula Bridge)	43	Bamongola
14	Choto Mohanpara-I	44	Habibpur
15	Deotala (Near Post Office)	45	Begamganj
16	Matoil	46	Debipur
17	Kokabeni	47	Nimasarai
18	IOL Petrol Pump, Harishchandrapur	48	Pandua
19	Mianhat (Janaki Nagar)	49	Pagla Bridge
20	Tulsihata	50	Paikpara
21	BDO Office, Harishchandrapur	51	Nalagola
22	Datian Primary School	53	Mashaldighi
23	Daulatpur Gram Panchayat Office	54	Gajol
24	Jagannathpur Primary School	55	Kadubari
25	Alinagar GPO, Nurnagar Mosque	57	Baliadanga Lower Buniadi School
26	Sujapur GPO, Choto Sujapur	58	Jalalpur GPO, Sherpur
27	Mothabari (High School)	60	PWD Godown, Malda Town
28	16 Mile	61	Muchia Panchayat Office
29	17 Mile	62	Ratua (TUBE WELL)

Fig. 6.8 Seasonal fluctuation in groundwater level (pre-monsoon versus post-monsoon, 2020), Malda district

6.8 Decadal (long-term) fluctuation in groundwater level

Apart from the seasonal fluctuation in groundwater level in Malda district, the long-term trend of either rise or decline in groundwater level has been calculated. For this the mean depth to water level (DTW) data for the pre-monsoon period for one decade (from 2010 to 2019, total 10 years) was calculated, which was then compared with pre-monsoon groundwater level data of 2020. Similarly, mean of long-term or decadal data (2010 to 2019) for post-monsoon period was compared with the post-monsoon, 2020 DTW data of Malda district. Subsequently, the long-term rise and/or decline in groundwater level, both for pre-monsoon and post-monsoon periods, were estimated. The data on long-term fluctuation in groundwater level for pre-monsoon period is summarized in **Table 5.4** whereas the long-term fluctuation for post-monsoon period is summarized in **Table 5.5.**

Table 6.4 Decadal fluctuation in groundwater level (pre-monsoon 2020 versus pre-monsoon, 2010-2019), Malda district

Sl. No.	Block Name	Location	Well No.	Well Type	Long-term DTW Pre-monsoon (2010-2019)	DTW Pre-monsoon, 2020	Rise (m)	Decline (m)
1.	Kaliachak-I	16 Mile	WBMD49	TW	6.78	2.46	4.32	--
2.	Kaliachak-I	Mahajantala	WBMD48	TW	5.96	1.66	4.30	--
3.	Kaliachak-III	17 Mile	WBMD47	TW	3.57	2.51	1.06	--
4.	Kaliachak-III	Doriapur	WBMD99	DW	4.70	3.12	1.58	--
5.	Kaliachak-III	Birnagar	WBMD59	TW	3.22	1.91	1.31	--
6.	Kaliachak-III	Pagla Bridge	WBMD89	TW	4.34	6.13	--	-1.79
7.	Manikchak	Begamganj	WBMD31B	DW	5.71	4.73	0.98	--
8.	Manikchak	Mohana-1	WBMD66	DW	5.60	4.07	1.53	--
9.	Manikchak	Mohana-2	WBMD67	DW	5.88	4.58	1.30	--
10.	Manikchak	Mohana-3	WBMD68	DW	4.91	6.93	--	-2.02
11.	Manikchak	Mohana-4	WBMD69	DW	6.06	5.62	0.44	--
12.	Bamongola	Bamongola	WBMD07C	TW	8.49	5.18	3.31	--
13.	Bamongola	Charakdanga	WBMD87	DW	5.65	1.01	4.64	--
14.	Bamongola	Makuli (Khiripara)	WBMD27	DW	5.03	0.95	4.08	--
15.	Bamongola	Nalagola	WBMD88	DW	4.00	0.38	3.62	--
16.	Bamongola	Paikpara	WBMD86	DW	6.87	1.88	4.99	--
17.	Habibpur	Habibpur	WBMD04	DW	6.31	3.38	2.93	--
18.	Habibpur	Tajpur	WBMD79	DW	5.05	1.94	3.11	--
19.	English Bazar	Battaly	WBMD09B	DW	6.07	2.22	3.85	--

Sl. No.	Block Name	Location	Well No.	Well Type	Long-term DTW Pre-monsoon (2010-2019)	DTW Pre-monsoon, 2020	Rise (m)	Decline (m)
20.	English Bazar	Bholanathpur	WBMD12	DW	3.26	0.87	2.39	--
21.	English Bazar	Choto Mohanpara-2	WBMD63	DW	7.28	5.25	2.03	--
22.	English Bazar	Choto Mohanpara-3	WBMD64	DW	6.99	5.59	1.40	--
23.	English Bazar	Milki	WBMD29	DW	6.32	5.10	1.22	--
24.	Ratua-I	Debipur	WBMD37B	DW	5.56	4.73	0.83	--
25.	Ratua-I	Ratua	WBMD42	TW	5.77	3.83	1.94	--
26.	Ratua-II	Peerganj	WBMD76	DW	7.94	6.02	1.92	--
27.	Gazole	Deotala	WBMD06	DW	2.67	0.77	1.90	--
28.	Gazole	Mashaldighi	WBMD15	DW	9.70	7.03	2.67	--
29.	Gazole	Matoil	WBMD91	TW	10.05	7.54	2.51	--
30.	Gazole	Pandua	WBMD16A	DW	4.29	1.77	2.52	--
31.	Gazole	Pandua-1	WBMD75	DW	11.31	6.50	4.81	--
32.	Harishchandrapur-I	Tulsihata	WBMD40	TW	6.93	3.83	3.10	--
33.	Harishchandrapur-II	Baroduari	WBMD41	DW	6.34	4.22	2.12	--
34.	Chanchal-II	Jalalpur	WBMD95	PZ	8.83	8.32	0.51	--
35.	Old Malda	Malda Town	WBMD14	DW	9.88	6.54	3.34	--
36.	Old Malda	Muchia	WBMD11	DW	7.26	4.94	2.32	--

Table 6.5 Decadal fluctuation in groundwater level (post-monsoon 2020 versus post-monsoon, 2010-2019), Malda district

Sl. No.	Block Name	Location	Well No.	Well Type	DTW (Post-monsoon 2020	Long-term Post-monsoon DTW (2010-2019)	Long-term Fluctuation Rise (m)	Long-term Fluctuation Decline (m)
1.	Kaliachak - I	16 Mile	WBMD49	TW	2.15	4.62	2.47	--
2.	Kaliachak - I	Pagla Bridge	WBMD89	TW	1.95	2.82	0.87	--
3.	Kaliachak - I	Kaliachak	WBMD83	DW	1.83	2.98	1.15	--
4.	Kaliachak - I	Khaschandpur	WBMD60	DW	2.94	3.59	0.65	--
5.	Kaliachak - II	Kuriatar	WBMD45A	TW	1.84	3.72	1.88	--
6.	Kaliachak - III	Doriapur	WBMD46A	TW	1.30	2.53	1.23	--
7.	Kaliachak - III	Birnagar	WBMD59	DW	1.55	2.02	0.47	--
8.	Kaliachak - III	17 Mile	WBMD47	TW	2.10	2.02	--	-0.08
9.	Gazole	Adina	WBMD81	DW	0.83	1.98	1.15	--
10.	Gazole	Deotala	WBMD06	DW	1.09	1.47	0.38	--
11.	Gazole	Kadubari	WBMD22	DW	1.31	2.97	1.66	--
12.	Gazole	Gazole	WBMD93	TW	1.24	2.77	1.53	--
13.	Gazole	Ghoksol	WBMD80	DW	1.43	3.10	1.67	--
14.	Gazole	Mashaldighi	WBMD15	DW	2.43	3.80	1.37	--
15.	Gazole	Matoil	WBMD73	DW	1.75	4.63	2.88	--
16.	Gazole	Panchamukhi	WBMD98	PZ	3.36	4.83	1.47	--
17.	Gazole	Pandua	WBMD16A	DW	1.10	2.20	1.10	--
18.	Bamongola	Bamongola	WBMD07C	TW	2.21	3.99	1.77	--
19.	Bamongola	Charakdanga	WBMD87	DW	0.80	3.10	2.30	--
20.	Bamongola	Paikpara	WBMD86	DW	1.95	1.84	--	-0.11

21.	Bamongola	Nalagola	WBMD88	DW	1.37	1.67	0.30	--
22.	Habibpur	Habibpur	WBMD04	DW	1.22	2.18	0.96	--
23.	Habibpur	Tajpur	WBMD79	DW	1.37	2.47	1.10	--
24.	Harishchandrapur-I	Tulsihata	WBMD40	TW	2.35	5.06	2.71	--
25.	Harishchandrapur-II	Baroduari	WBMD41	DW	3.04	4.39	1.35	--
26.	English Bazar	Battaly	WBMD09B	DW	1.54	4.82	3.28	--
27.	English Bazar	Bholanathpur	WBMD12	DW	0.58	2.04	1.46	--
28.	English Bazar	ChotoMohanpara	WBMD64	DW	3.72	5.66	1.94	--
29.	English Bazar	Milki	WBMD29	DW	2.04	4.92	2.88	--
30.	Manikchak	Mohana - 1	WBMD66	DW	2.75	3.75	1.00	--
31.	Manikchak	Najirpur	WBMD31B	DW	2.67	3.71	1.04	--
32.	Manikchak	Begamganj	WBMD70	DW	2.62	3.64	1.02	--
33.	Ratua - I	Bhaluka	WBMD21	PZ	4.19	4.73	0.54	--
34.	Ratua – I	Ratua	WBMD17A	DW	3.36	4.17	0.82	--
35.	Ratua - I	Ratua	WBMD42	TW	5.90	4.11	--	-1.79
36.	Ratua - I	Debipur	WBMD37B	DW	3.71	3.46	--	-0.25
37.	Old Malda	Jadupur	WBMD82	DW	2.65	5.30	2.65	--
38.	Old Malda	Aiho	WBMD85	DW	0.49	2.04	1.55	--
39.	Old Malda	Malda Town	WBMD14	DW	1.79	3.58	1.79	--
40.	Chanchal - II	Jalalpur	WBMD95	PZ	5.96	7.22	1.26	--

6.9 Pre-monsoon and post-monsoon long term (decadal) trend analysis

A study of the data in **Table 6.4** and **Table 6.5** indicates that during pre-monsoon, long-term (decadal) variation in groundwater level was widely variable. In pre-monsoon, the minimum decadal rise in groundwater level was 0.44 m at Mohana in Manikchak block, followed by 0.51 m at Jalalpur in Chanchal-II block. The maximum decadal rise of 4.99 m was observed at Paikpara in Bamongola block, followed by 4.81 m at Pandua in Gazole block. It is also seen that decadal decline (fall) was recorded in only two monitoring wells out of 36, which is only 5.56% of the total number of wells for which long-term groundwater level data is available. A perusal of the data indicates that decadal decline of 1.79 m was observed at Pagla Bridge in Kaliachak-III block. Long-term decline of 2.02 m was also observed in a dug well at Mohana in Manikchak block. The decadal fluctuation map for pre-monsoon (pre-monsoon 2020 versus pre-monsoon 2010-2019) of Malda district is shown in **Fig. 6.9.**

During post-monsoon, the decadal fluctuation in groundwater level has been calculated for 40 groundwater monitoring wells. The data given in **Table 5.5** indicates that the minimum decadal (long-term) rise of 0.30 m was recorded at Nalagola in Bamongola block, followed by 0.38 m at Deotala in Gazole block. The highest decadal rise in groundwater level (3.28 m) was recorded at Battally in English Bazar block, followed by decadal rise of 2.88 m at Maoil in Gazole block and at Milki in English Bazar block. The minimum decadal fall (decline) of 0.08 m was observed in a tube well at 17 Mile in Kaliachak-III block, followed by 0.11 m at Paikpara in Bamongola block. The maximum decadal decline of 1.79 m was observed at Ratua, the block headquarters of Ratua-I block. It has been also revealed that only four out of 40 monitoring wells viz. 10% of total number of wells have shown long-term decline in groundwater level. The decadal fluctuation map for post-monsoon (post-monsoon 2020 versus post-monsoon 2010-2019) of Malda district is shown in **Fig. 6.10.**

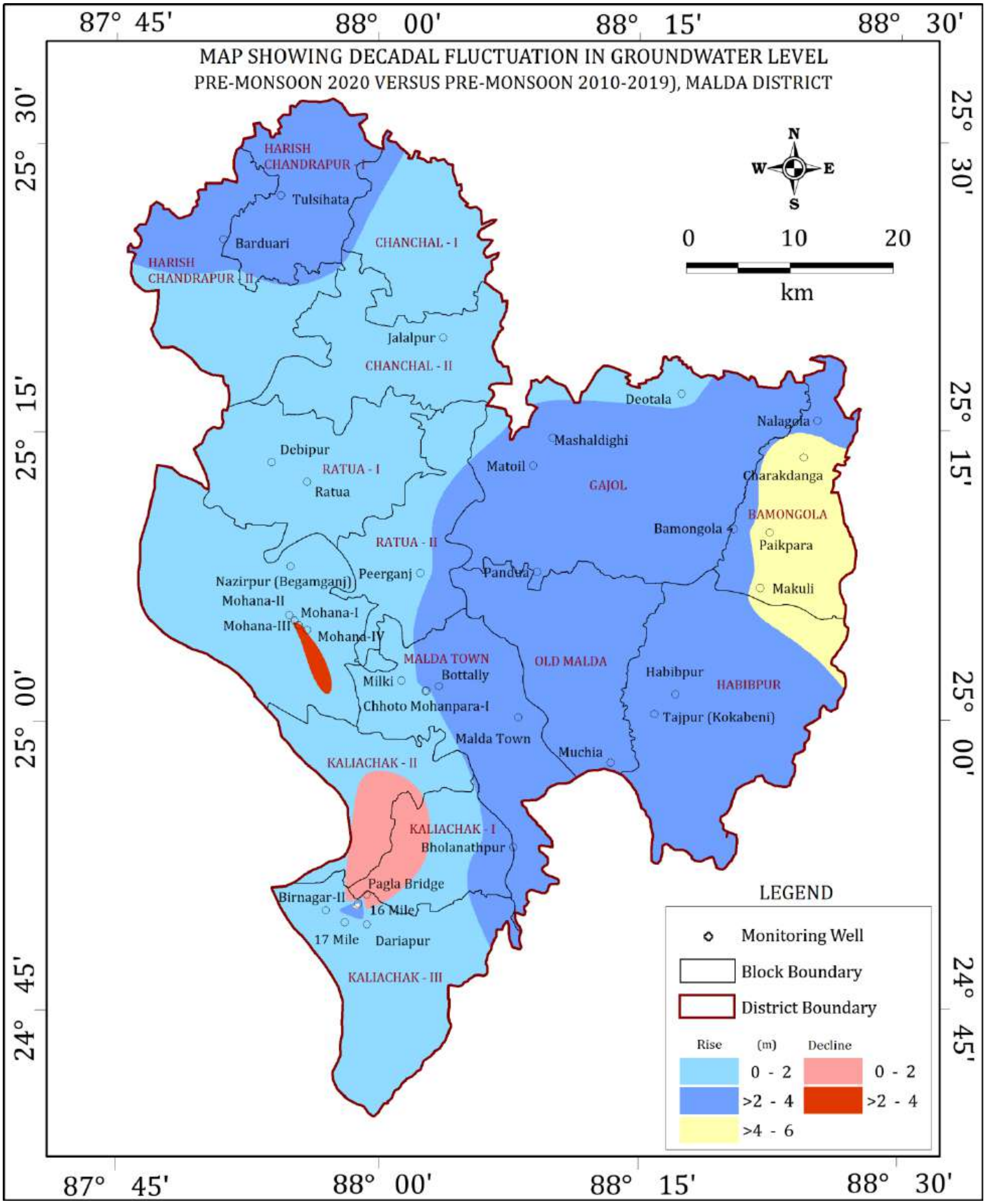


Fig. 6.9 Map showing decadal fluctuation in groundwater level (pre-monsoon 2020 versus pre-monsoon 2010-2019), Malda district

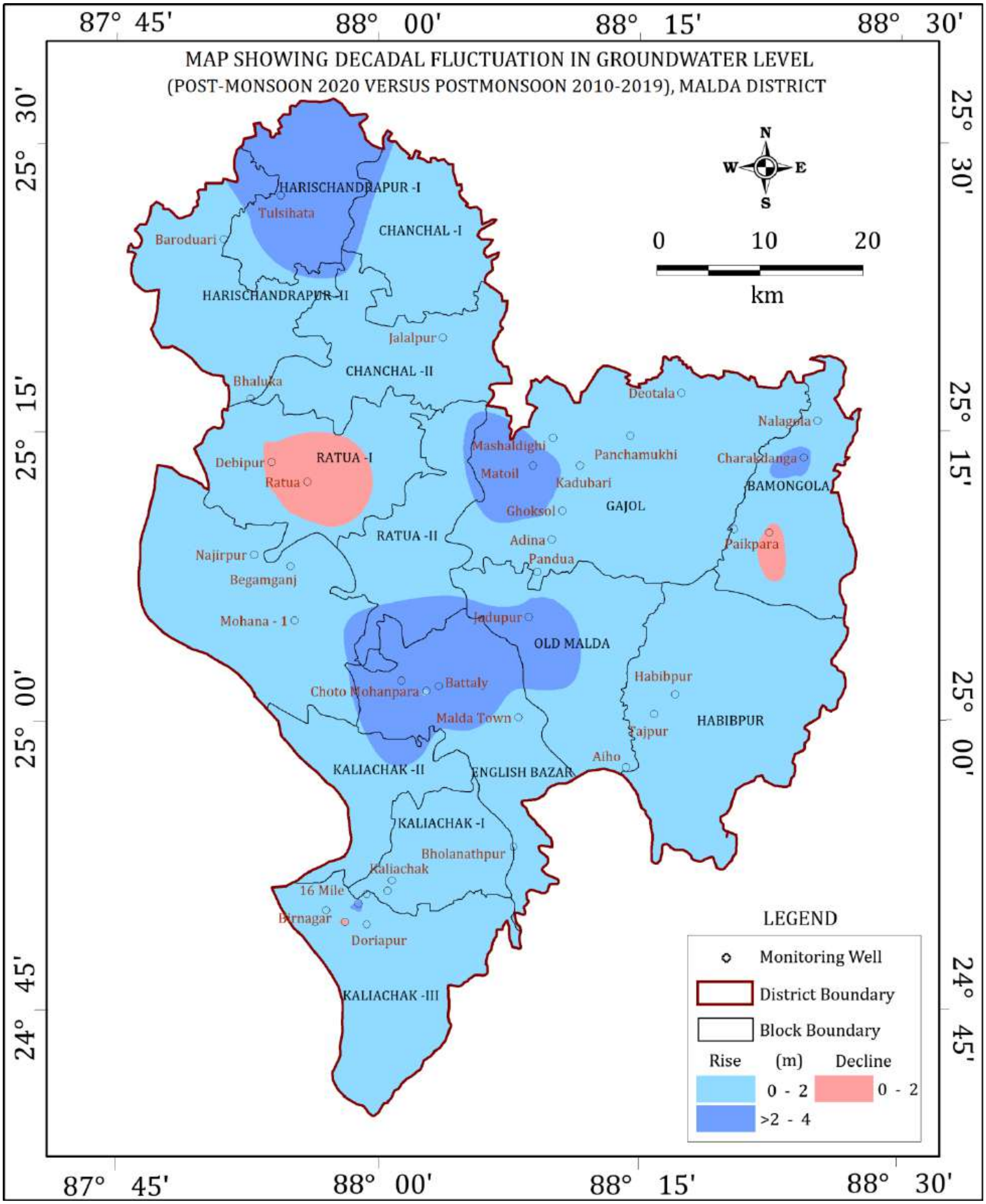


Fig. 6.10 Map showing decadal fluctuation in groundwater level (post-monsoon 2020 versus post-monsoon, 2010-2019), Malda district

6.10 Groundwater resources

Dynamic Groundwater Resources of Malda district (as on 31st March, 2013) was estimated jointly by CGWB and SWID, Government of West Bengal, following the methodology recommended by Groundwater Resources Estimation Committee (GEC, 1997). Though assessment of dynamic ground water resources has been completed for a later period (as on 31st March 2017), the resources are yet to be validated through Government Order by the Government of West Bengal. Accordingly, dynamic ground water resources (as on 31-3-2013) have been considered for inclusion in the present report.

Dynamic groundwater resources have been estimated separately for both the command and non-command areas of Malda district. As per the assessment, two blocks viz. Habibpur and Harishchandrapur-I were in the Semi-critical category of groundwater development, as on 31st March 2013. Details of these blocks along with valid reasons for categorization of the blocks are presented in **Table 6.6.** A summary of dynamic ground water resources of the district is given below.

1. Total Ground Water Recharge	150784.98ham
2. Provision for Natural Discharge	4697.37ham
3. Net Annual Ground Water Availability	136087.61ham
4. Existing Ground Water Draft for Irrigation	59108.60 ham
5. Existing Ground Water Draft for Domestic Use	4261.62 ham
6. Existing Ground Water Draft for Industrial Use	2130.81 ham
7. Existing Ground Water Draft for All Uses	65501.03 ham
8. Stage of Ground Water Development (SOD)	48.13 %
9. Allocation for Domestic and Industrial Water Supply for 25 years (up to 2038)	9828.37 ham
10. Net Ground Water Availability for Future Irrigation Development	67150.64 ham
11. Categorization of Block	Safe: 13 Semi-critical: 02

For estimation of dynamic ground water resources, the number of ground water abstraction structures (dug wells, shallow tube wells and deep tube wells), depth to water level (DTW) in the monitoring wells and rainfall are important parameters. A table showing the input parameters utilized for assessment of the resources (as on 31-3-2013) is given in **Table 6.7.** A summary table of the salient findings of the dynamic ground water resources (as on 31-3-2013), which also gives block wise data on ground water resources of Malda district, is given in **Table 6.8.**

Table 6.6 Details of two Semi-critical Blocks in Malda district (as on 31-3-2013)

Name of Block (Ground Water Assessment Unit)	Nature of Ground Water Assessment Sub- Unit	Stage of Ground Water Development (SOD) %	Is there a significant decline of water level trend ('+' denotes falling and '-' denotes rising trend)				Category as per SOD	Categorization done based on
			Trend (cm/yr)	Pre-monsoon	Trend (cm/yr)	Post-monsoon		
Habibpur	Command	--	--	--	--	--	--	Water Level Trend
	Non-Command	19.92	21.43	Yes	23.50	Yes	Semi-critical	
	Poor Ground Water Quality	--	--	--	--	--	--	
Harishchandrapur-I	Command	--	Nil	Nil	Nil	Nil	--	Stage of Development
	Non-Command	93.18	9.82	No	13.87	No	Semi-critical	
	Poor Ground Water Quality	--	Nil	Nil	Nil	Nil	--	

Table 6.7 Input parameters utilized for estimation of dynamic groundwater resources of Malda district (as on 31-3-2013)

Block	Rainfall (mm)	Avg. Pre-monsoon Water Level (m bgl)	Avg. Post-monsoon Water Level (m bgl)	Avg. Seasonal Fluctuation (m)	No. of DTW	No. of STW	No. of DW
Bamongola	1212.66	17.21	11.21	5.99	0	403	0
Chanchal-I	1261.08	6.58	4.84	1.75	30	1831	6
Chanchal-II	1221.77	7.56	6.60	0.96	38	2942	8
English Bazar	954.14	6.09	5.34	0.76	53	1583	0
Gazole	1120.20	9.36	6.44	2.92	26	2613	10
Habibpur	1062.40	17.71	14.86	2.85	1	1382	4
Harishchandrapur-I	1294.97	5.82	5.24	0.58	13	3020	0
Harishchandrapur-II	1285.59	5.24	3.22	2.02	13	4303	6
Kaliachak-I	995.25	4.83	3.56	1.27	15	1590	1
Kaliachak-II	1004.26	4.45	3.82	0.63	27	1042	1
Kaliachak-III	1054.58	4.33	2.97	1.36	38	3883	2
Manikchak	1115.72	5.33	3.62	1.72	21	1416	9
Old Malda	945.51	9.18	7.53	1.65	61	1085	1
Ratua-I	1154.35	7.10	5.03	2.07	35	2537	4
Ratua-II	1052.29	8.78	5.99	2.79	28	2061	8
TOTAL	--	--	--	--	**399**	**31691**	**60**

Table 6.8 Block wise groundwater resource of Malda district (as on 31-3-2013)

Name of Groundwater Assessment Unit	Type of Groundwater Assessment Sub-unit	Recharge from Rainfall (ham)		Recharge from Other Sources (ham)		Total Annual Ground Water Recharge (ham)	Provision for Natural Discharge(ham)	Net Annual Ground Water Avail-ability (ham)	Existing Gross Ground Water Draft for irrigation (ham)	Existing Ground Water Draft for Domestic Use (ham)	Existing Ground Water Draft for Industrial Use (ham)	Existing Gross Ground Water Draft for All Uses (ham)	Provision for domestic and industrial requirement up to 2035 (ham)	Net Ground Water Availability for future irrigation development (ham)	Stage of Ground Water Development (%)
		Monsoon	Non-monsoon	Monsoon	Non-monsoon										
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Bamongola	Non-Command	5544.74	1165.45	381.77	617.92	7709.88	770.99	6938.89	644.80	164.81	82.40	892.01	380.09	5914.00	12.86
Chanchal-I	Non-Command	4755.55	1009.48	518.97	1338.68	7622.67	381.13	7241.54	3562.00	225.62	112.81	3900.43	520.33	3159.21	53.86
Chanchal-II	Non-Command	4052.52	1277.70	608.94	1742.74	7681.89	768.19	6913.70	5508.40	213.95	106.97	5829.32	493.41	911.89	84.32
English Bazar	Non-Command	4809.16	1516.26	422.30	1245.30	7993.02	799.30	7193.72	3645.80	502.12	251.06	4398.97	1158.00	2389.92	61.15
Gazole	Non-Command	13831.57	2907.26	2936.15	5080.35	24755.33	2475.53	22279.80	4730.80	381.70	190.85	5303.35	880.29	16668.71	23.80
Habibpur	Non-Command	10665.37	2241.76	411.25	1173.00	14491.37	1449.14	13042.23	2233.80	243.03	121.52	2598.35	560.49	10247.94	19.92
Harishchandrapur-II	Non-Command	6433.93	1352.35	671.51	2344.02	10801.81	1080.18	9721.63	7160.20	256.49	128.24	7544.93	591.53	1969.90	77.61

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Kaliachak-I	Non-Command	3121.14	656.03	283.89	685.24	4746.30	474.63	4271.67	2859.40	402.70	201.35	3463.46	928.74	483.53	81.08
Kaliachak-I	Non-Command	4398.30	1386.72	207.74	464.80	6457.55	645.76	5811.79	2234.60	273.80	136.90	2645.30	631.45	2945.74	45.52
Kaliachak-I	Non-Command	7704.96	1619.51	644.12	1698.97	11667.56	1166.76	10500.80	7011.60	368.31	184.15	7564.06	849.41	2639.79	72.03
Manikchak	Non-Command	9531.08	2003.34	320.72	650.45	12505.59	1250.56	11255.03	2710.20	277.32	138.66	3126.19	639.58	7905.25	27.78
Old Malda	Non-Command	6049.64	1271.58	319.83	1408.74	9049.79	904.98	8144.81	3017.40	251.53	125.77	3394.70	580.11	4547.30	41.68
Ratua-I	Non-Command	6828.48	1435.28	504.45	1580.27	10348.48	1034.85	9313.63	4795.80	281.51	140.75	5218.06	649.23	3868.60	56.03
Ratua-II	Non-Command	5151.95	1082.89	489.75	1765.31	8489.89	848.99	7640.90	3888.80	208.39	104.20	4201.39	480.61	3271.49	54.99
TOTAL DISTRICT		**96263.27**	**21992.81**	**9181.20**	**23347.70**	**150784.98**	**14697.37**	**136087.61**	**59108.60**	**4261.62**	**2130.81**	**65501.03**	**9828.37**	**67150.64**	**48.13**

WATER TABLE MAP (PRE-MONSOON 2020)
BLOCKS OF MALDA DISTRICT

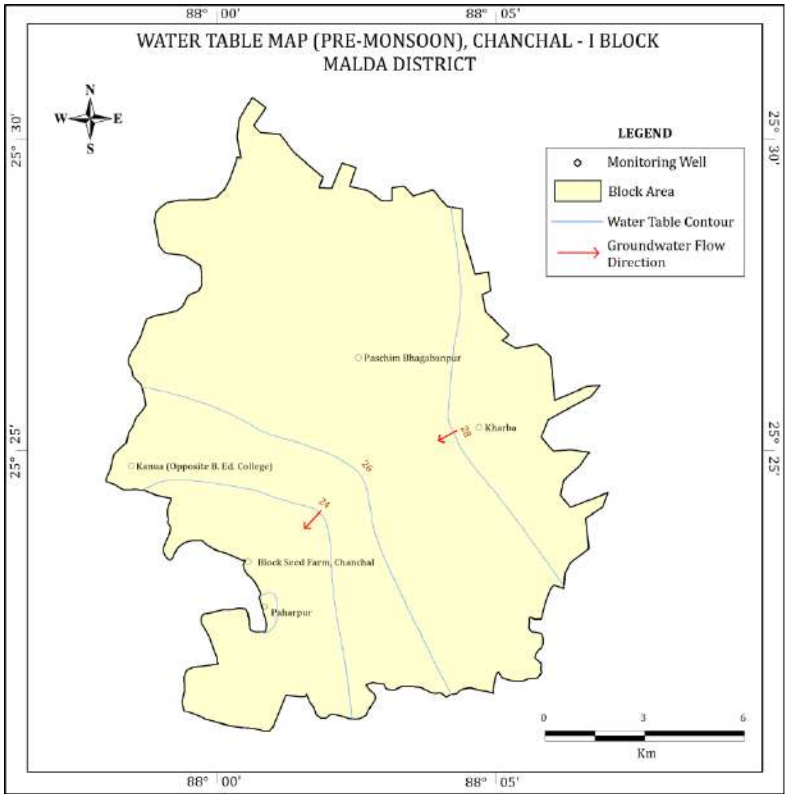


Fig. 6.11 Water table map (pre-monsoon 2020), Chanchal-I block

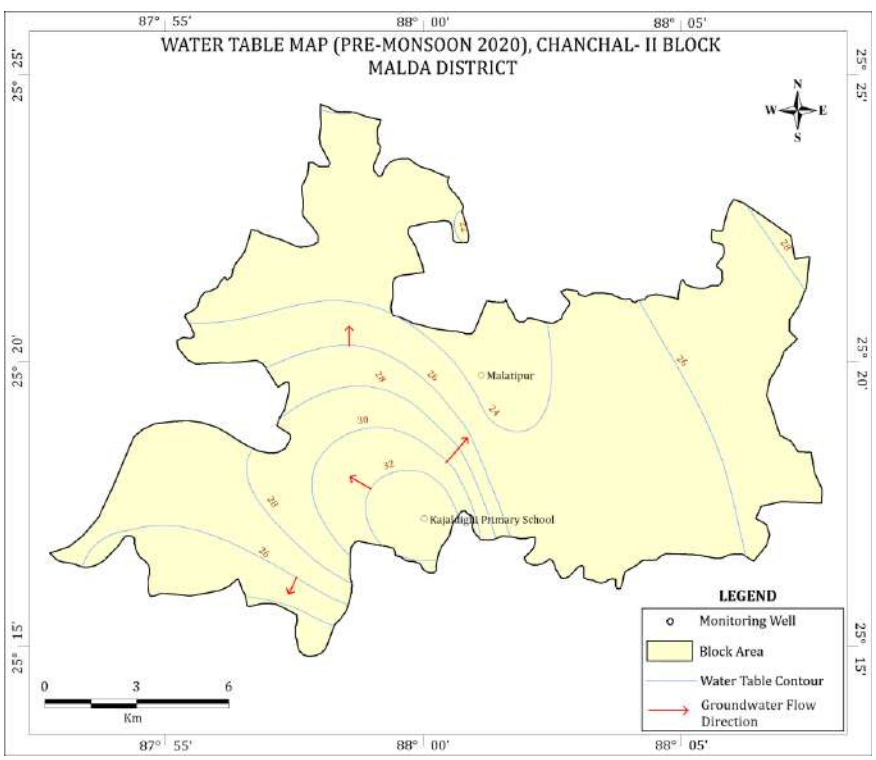


Fig. 6.12 Water table map (pre-monsoon 2020), Chanchal-II block

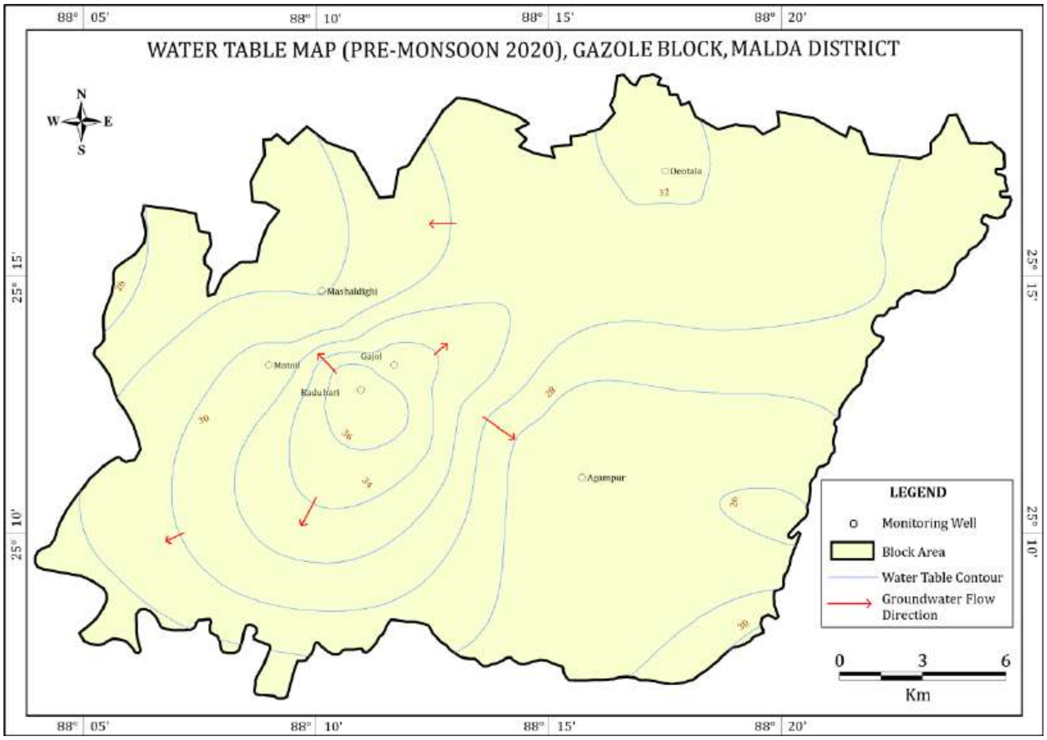


Fig. 6.13 Water table map (pre-monsoon 2020), Gazole block

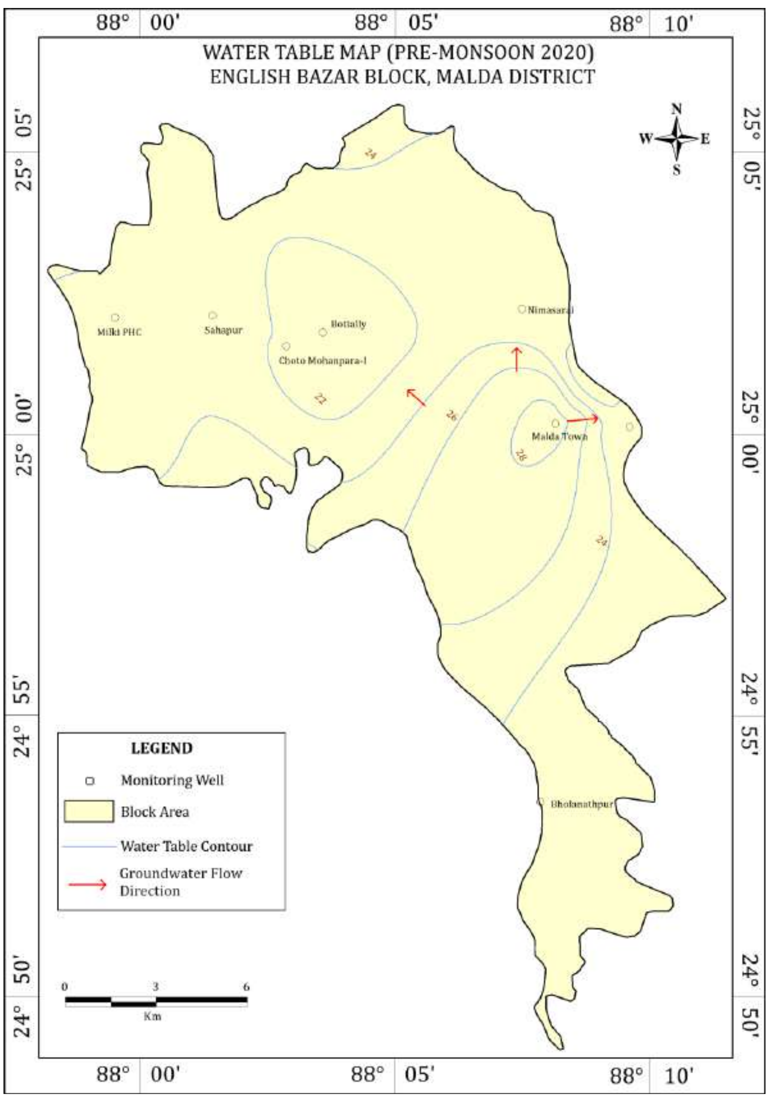


Fig. 6.14 Water table map (pre-monsoon 2020), English Bazar block

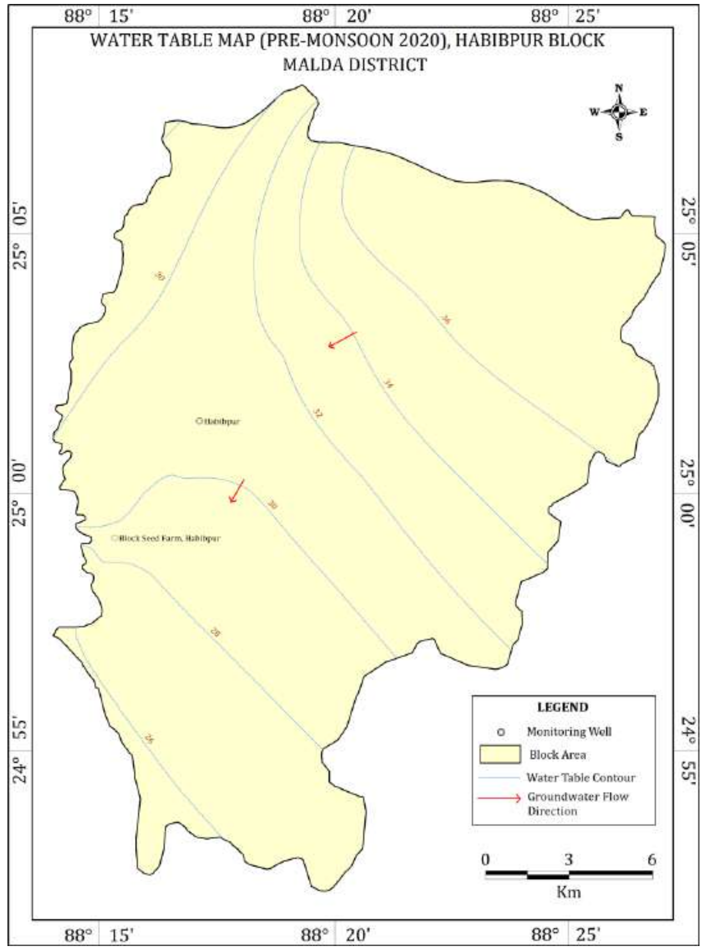


Fig. 6.15 Water table map (pre-monsoon 2020), Habibpur

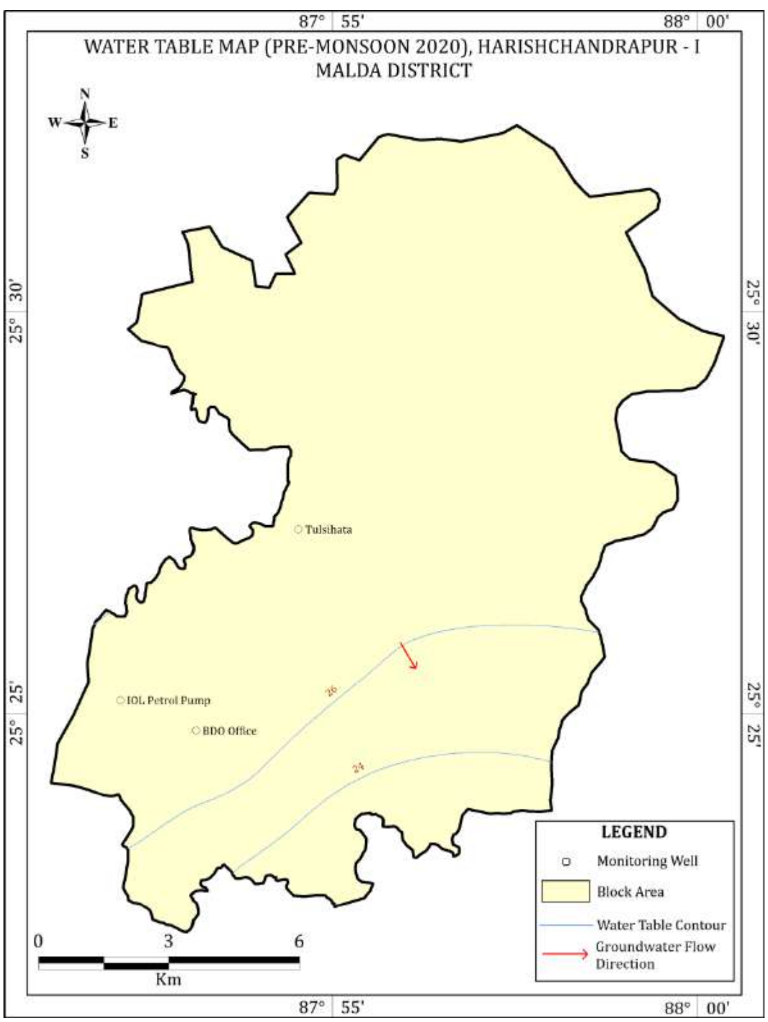


Fig. 6.16 Water table map (pre-monsoon 2020), Harishchandrapur-I block

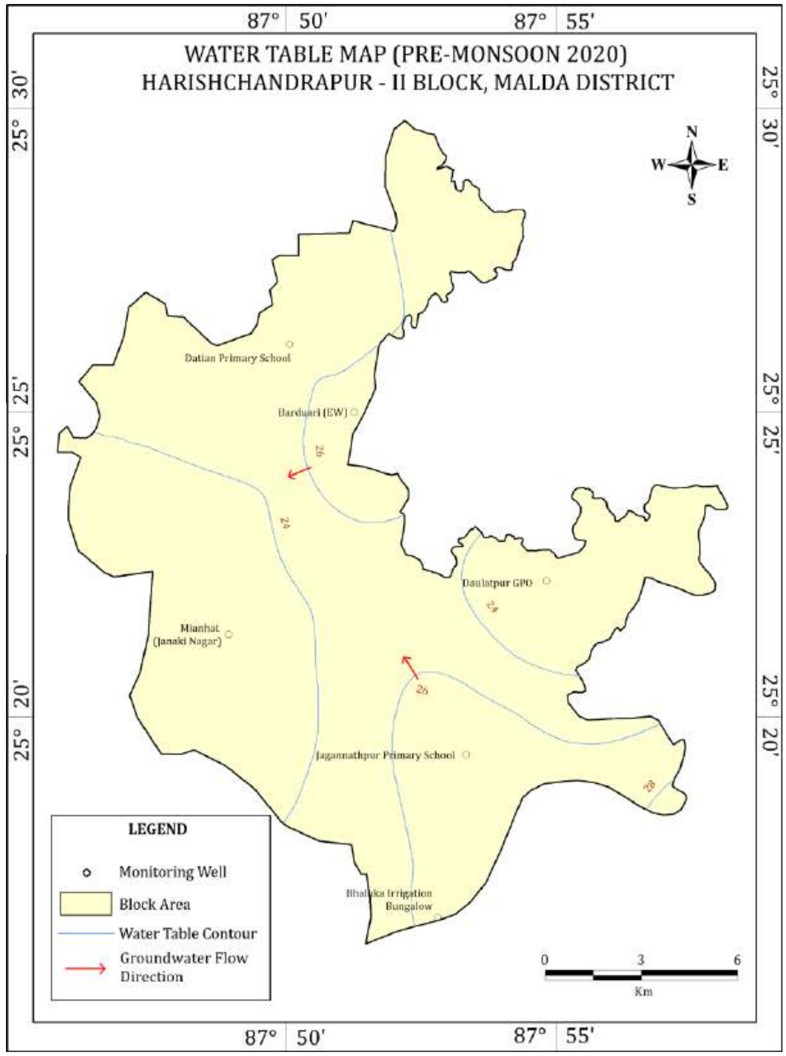


Fig. 6.17 Water table map (pre-monsoon 2020), Harishchandrapur-II block

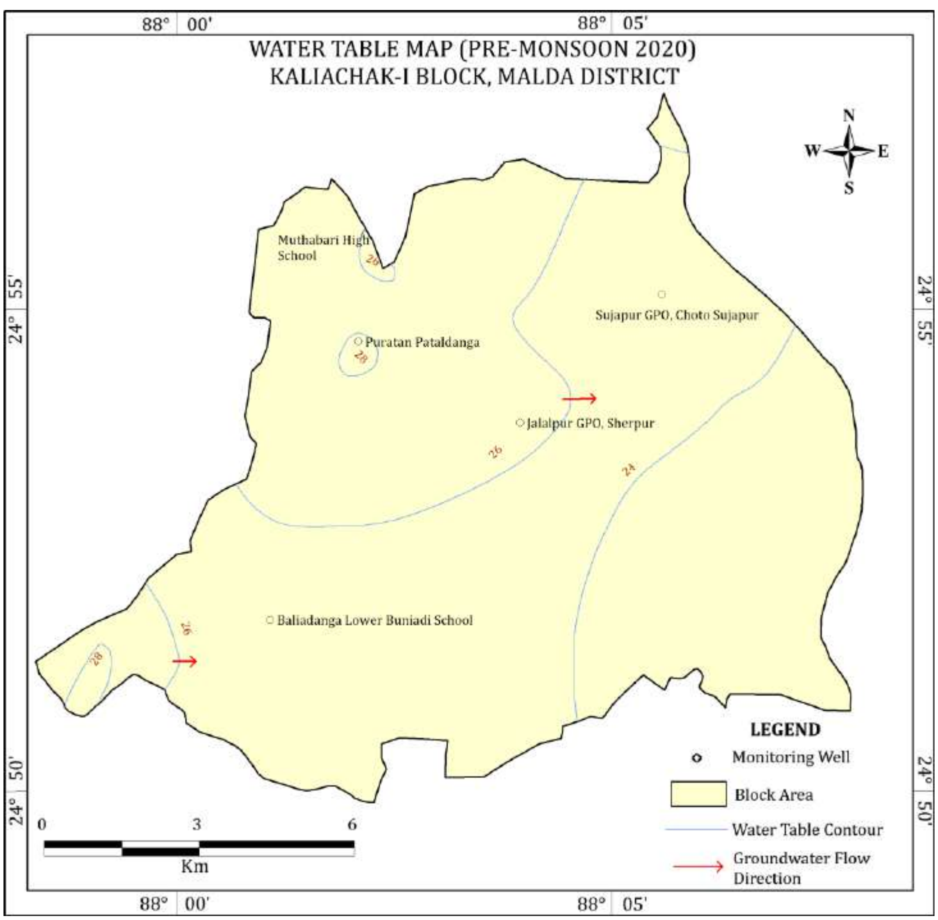


Fig. 6.18 Water table map (pre-monsoon 2020), Kaliachak-I block

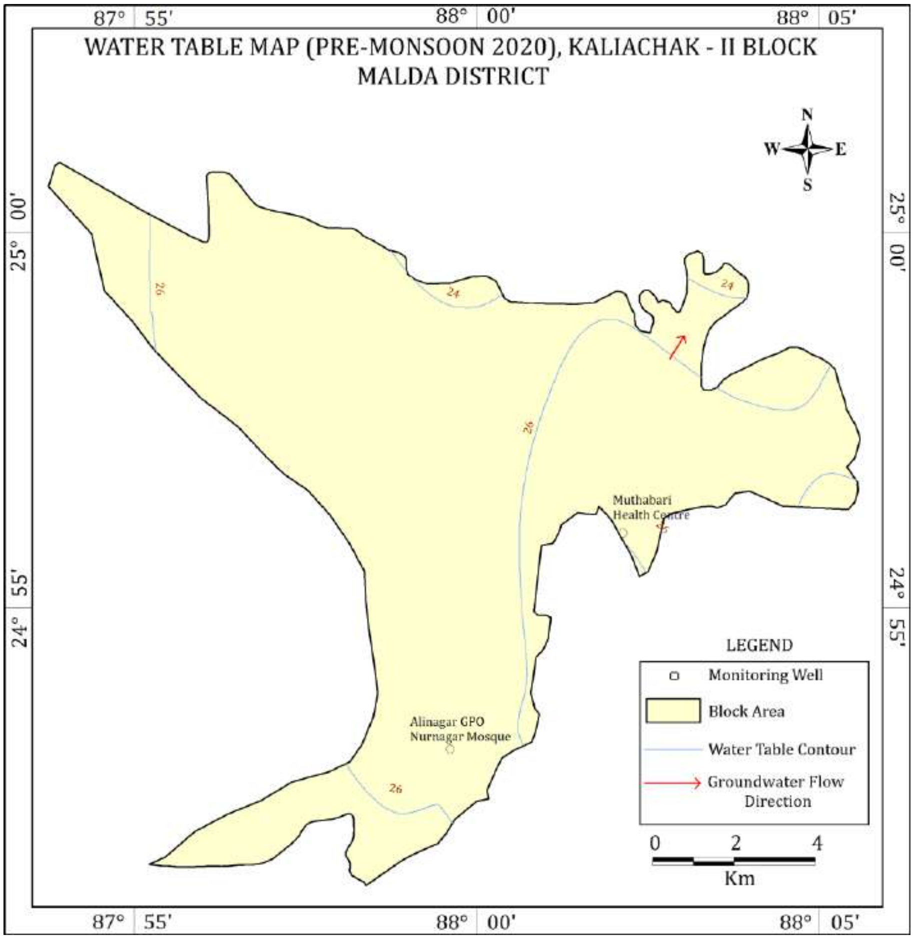


Fig. 6.19 Water table map (pre-monsoon 2020), Kaliachak-II block

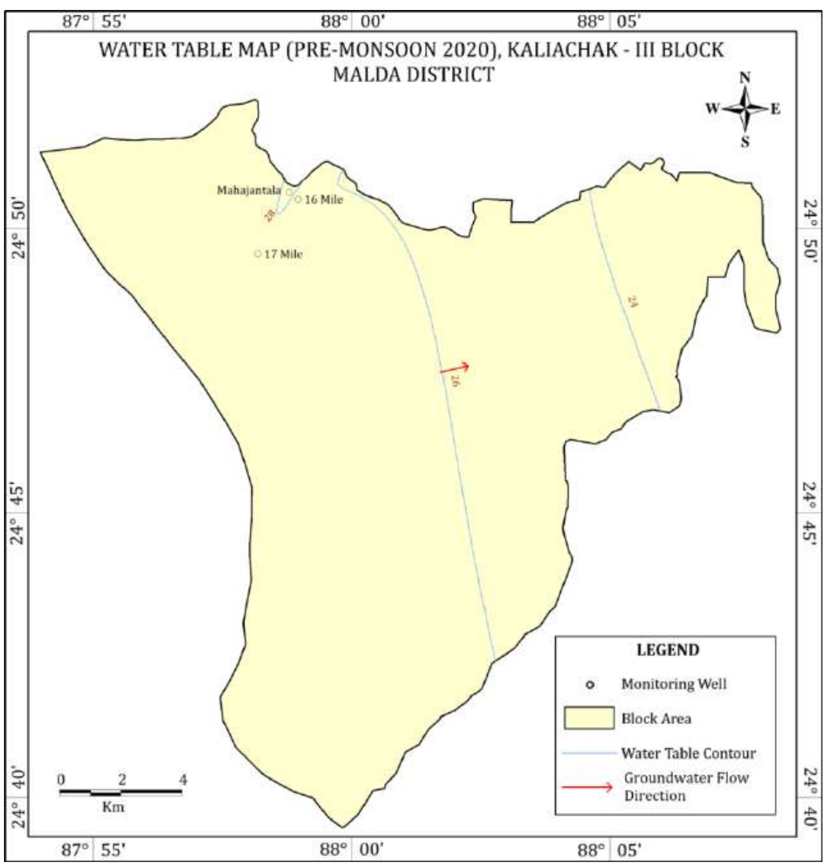


Fig. 6.20 Water table map (pre-monsoon 2020), Kaliachak-III block

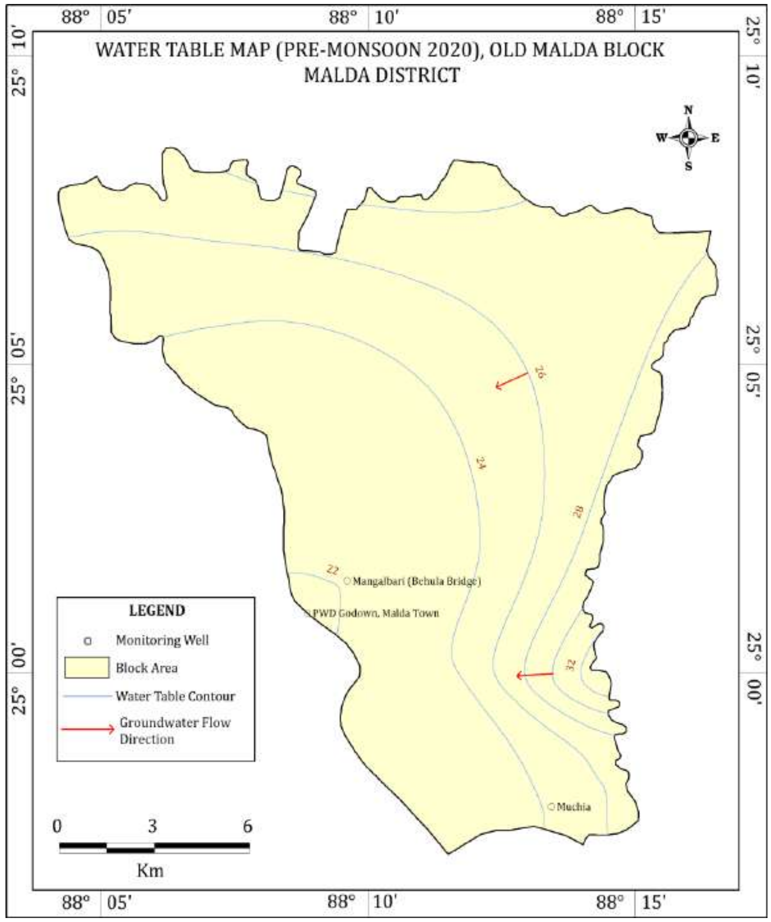


Fig. 6.21 Water table map (pre-monsoon 2020), Old Malda block

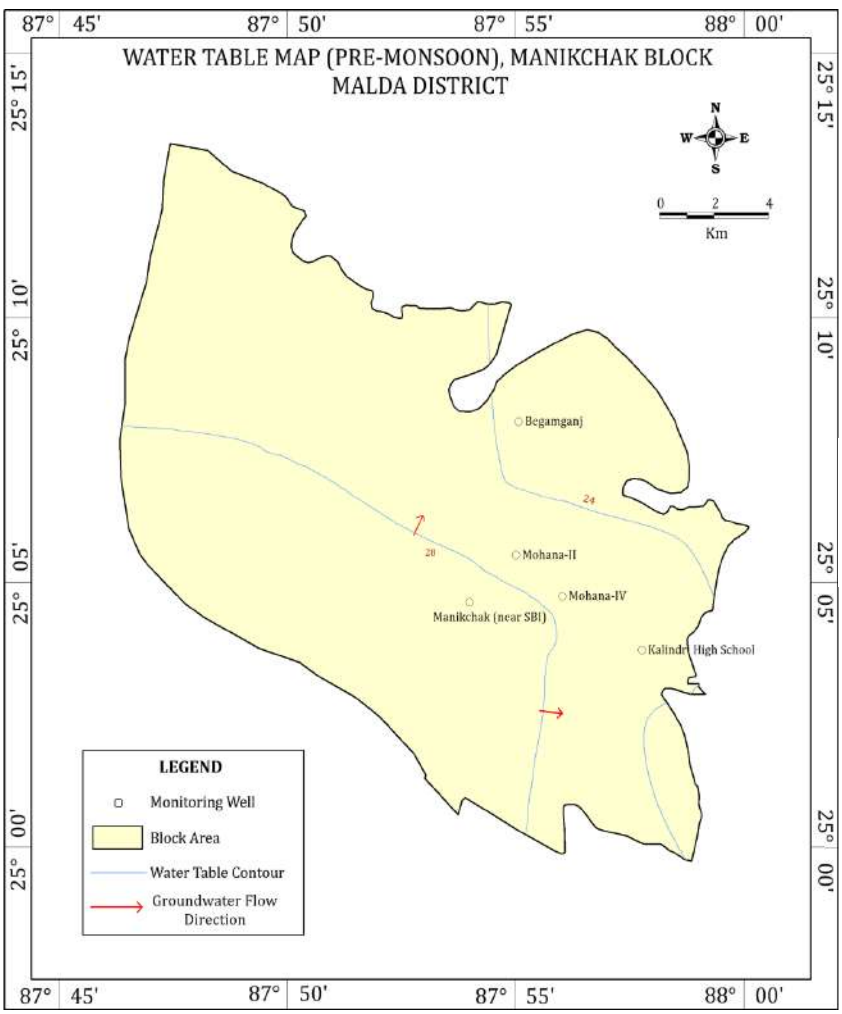


Fig. 6.22 Water table map (pre-monsoon 2020), Manikchak block

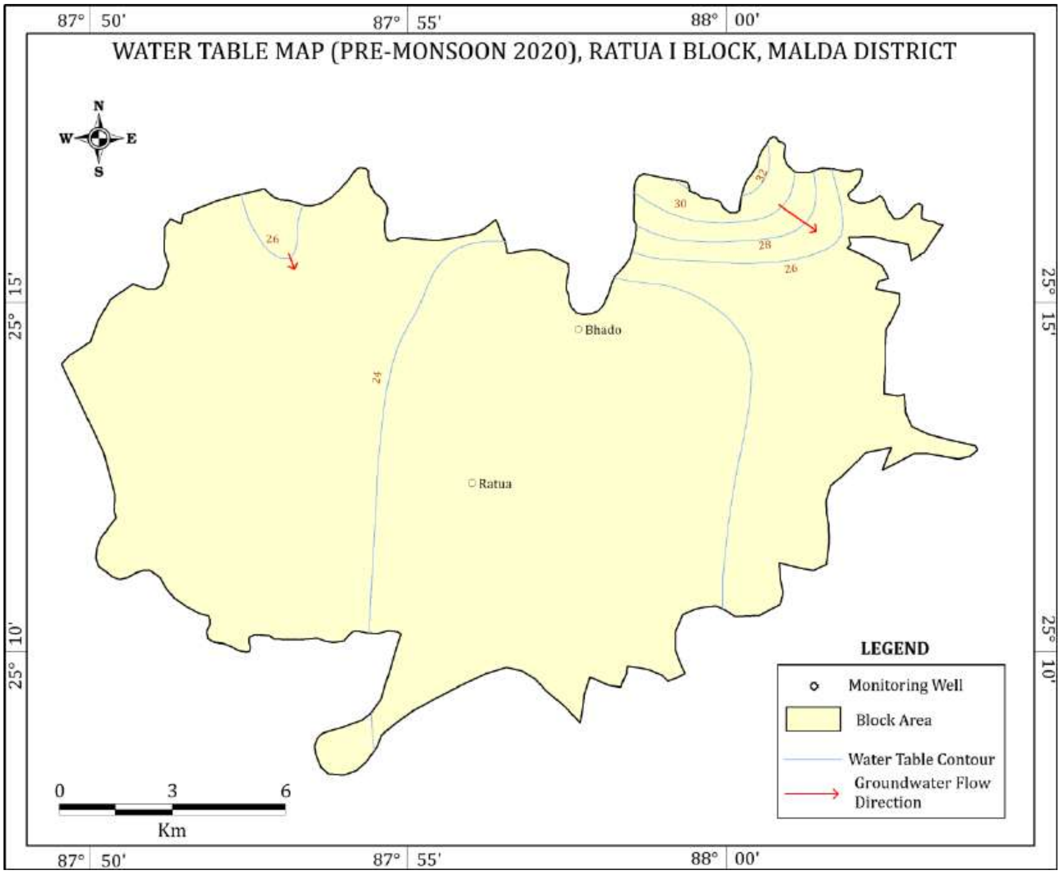


Fig. 6.23 Water table map (pre-monsoon 2020), Ratua-I block

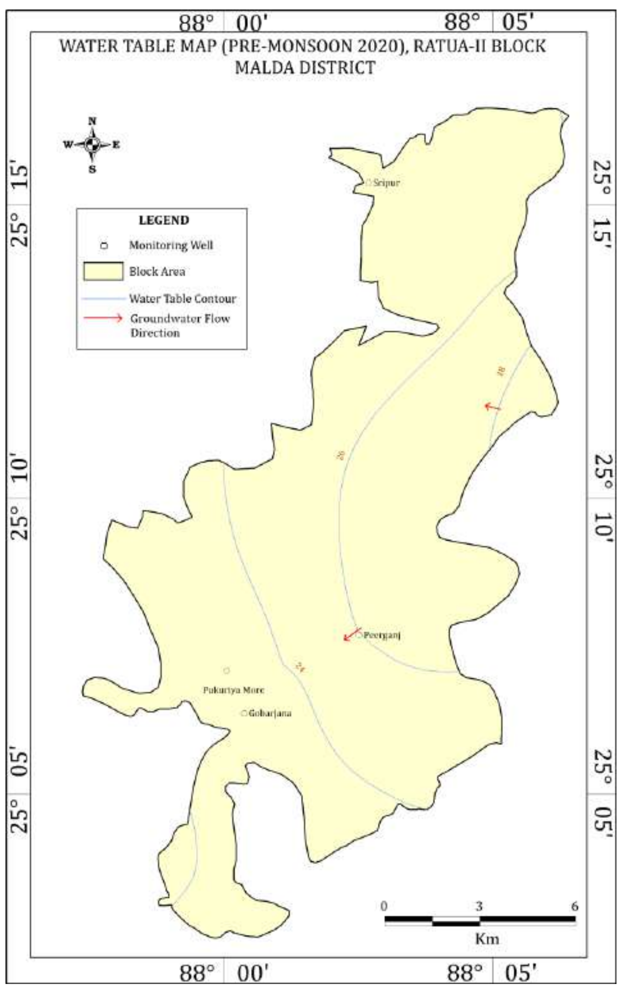


Fig. 6.24 Water table map (pre-monsoon 2020), Ratua-II block

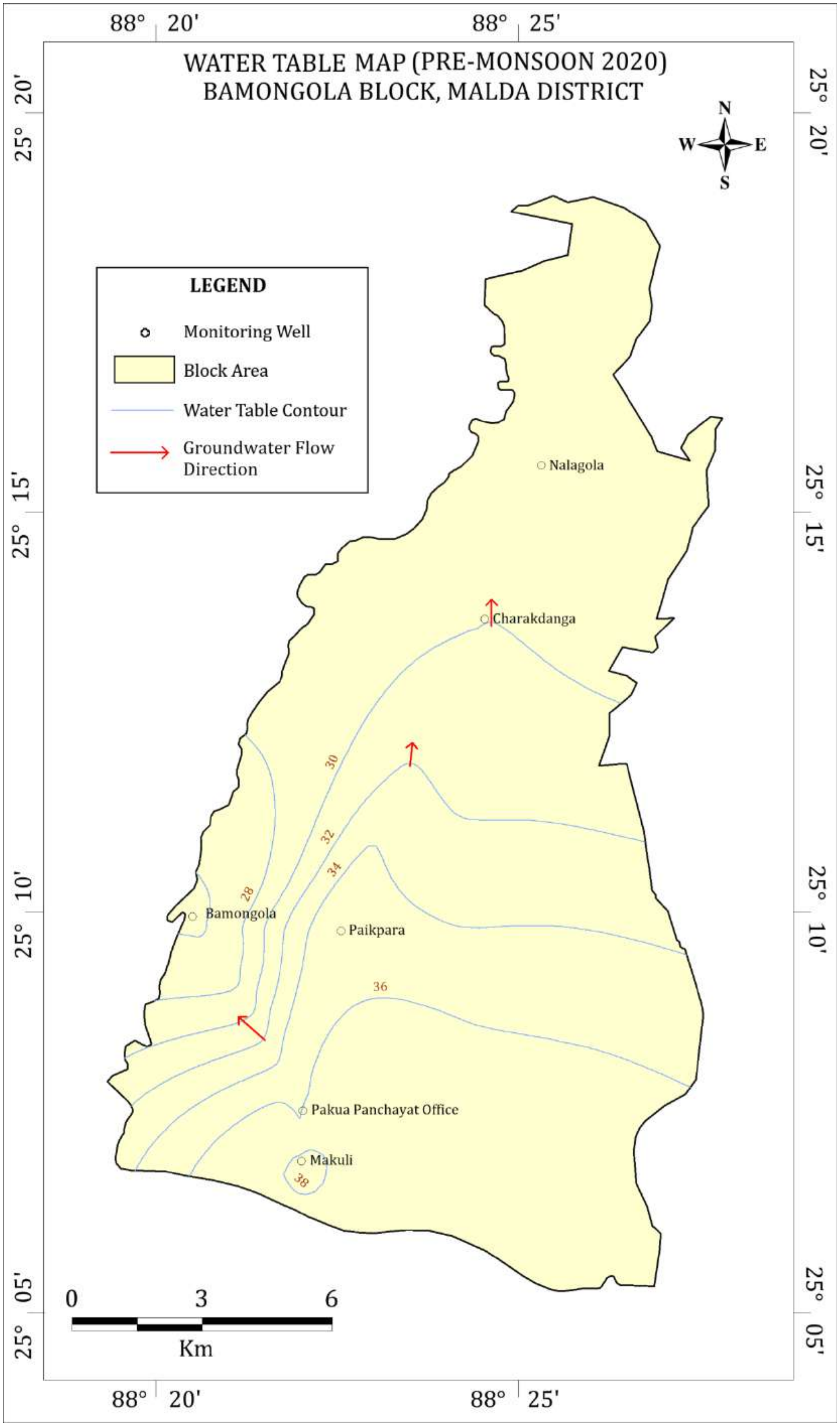


Fig. 6.25 Water table map (pre-monsoon 2020), Bamongola block

WATER TABLE MAP (POST-MONSOON 2020)
BLOCKS OF MALDA DISTRICT

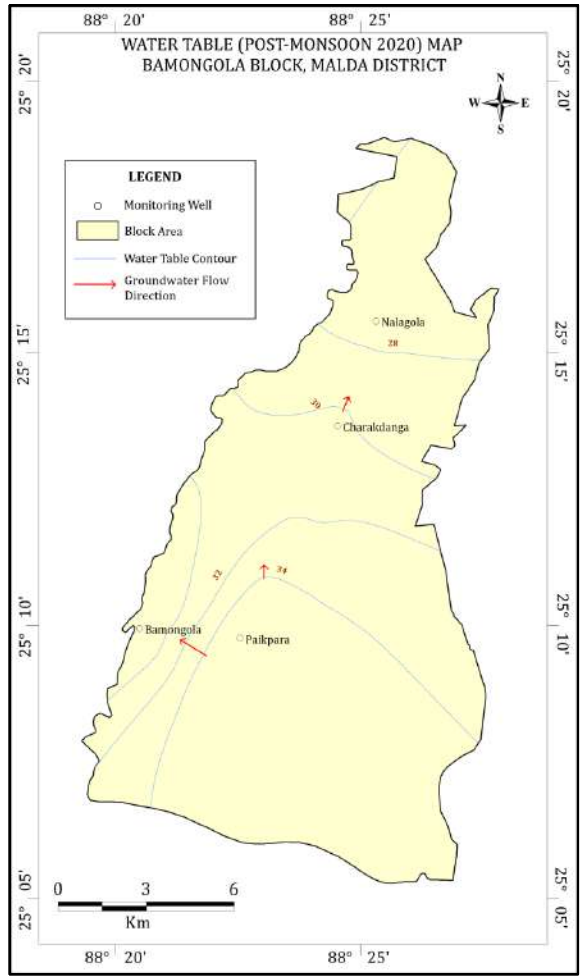


Fig. 6.26 Water table map (post-monsoon 2020), Bamongola block

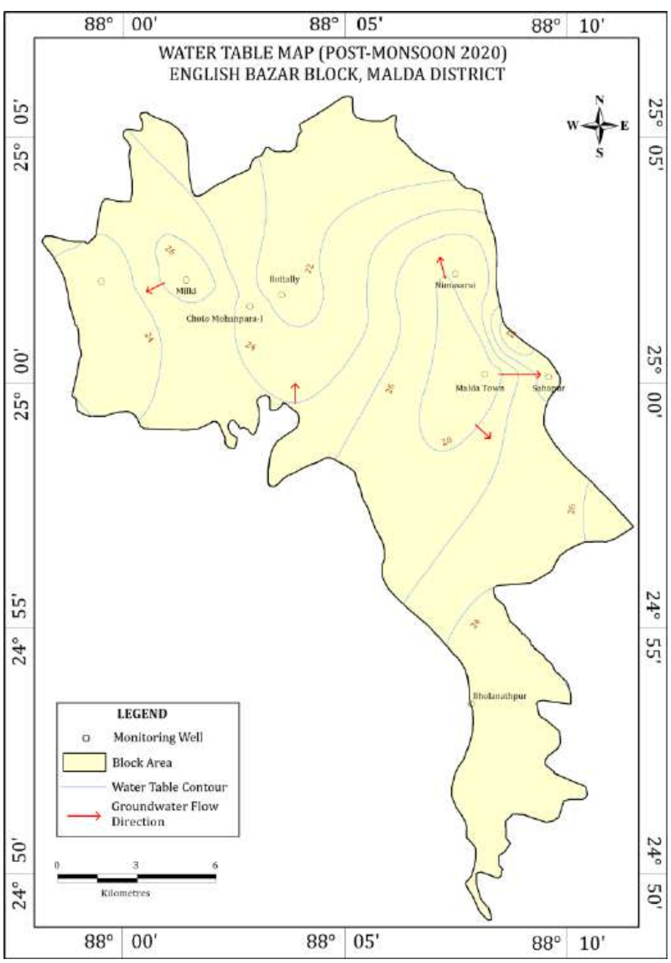


Fig. 6.27 Water table map (post-monsoon 2020), English Bazar block

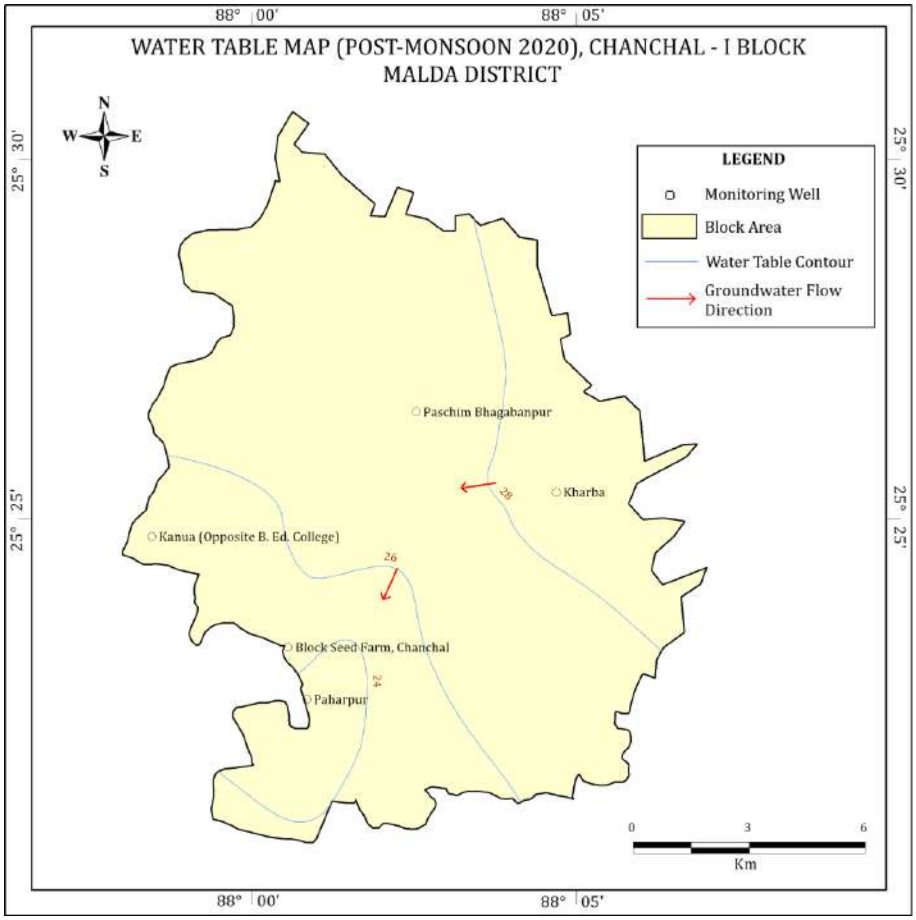


Fig. 6.28 Water table map (post-monsoon 2020), Chanchal-I block

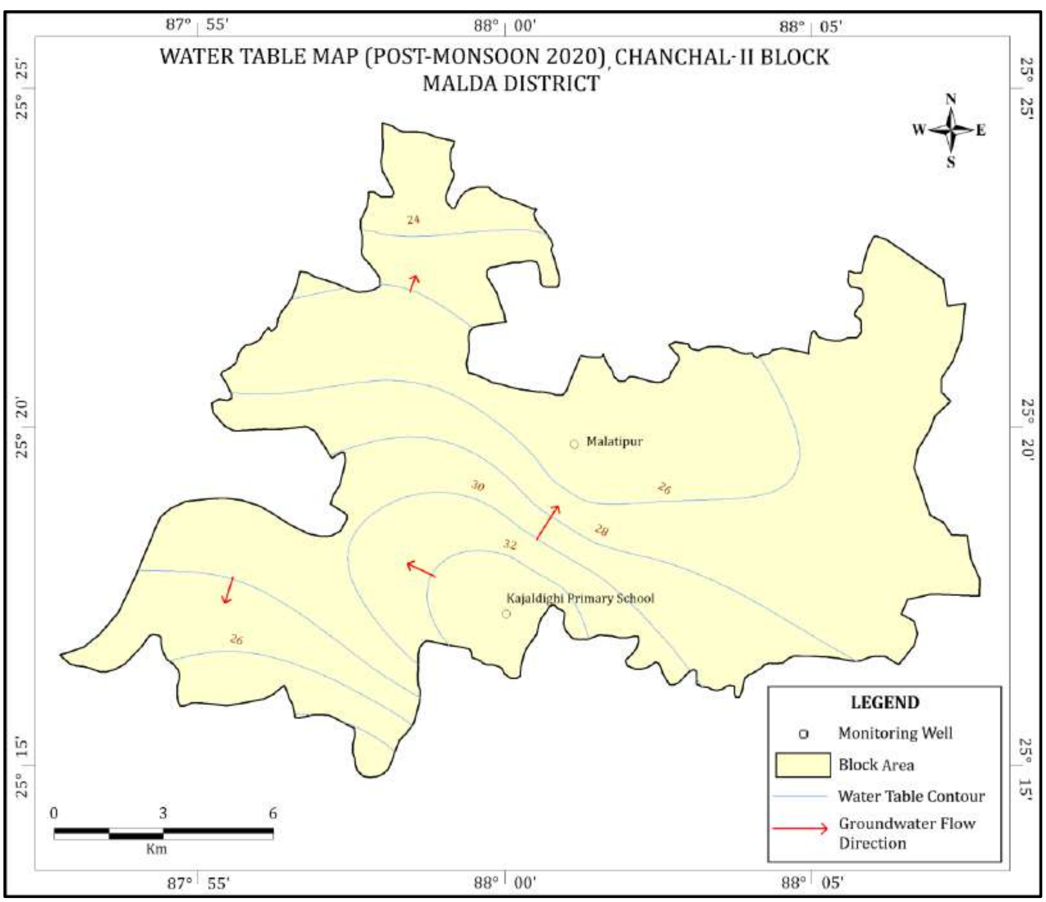


Fig. 6.29 Water table map (post-monsoon 2020), Chanchal-II block

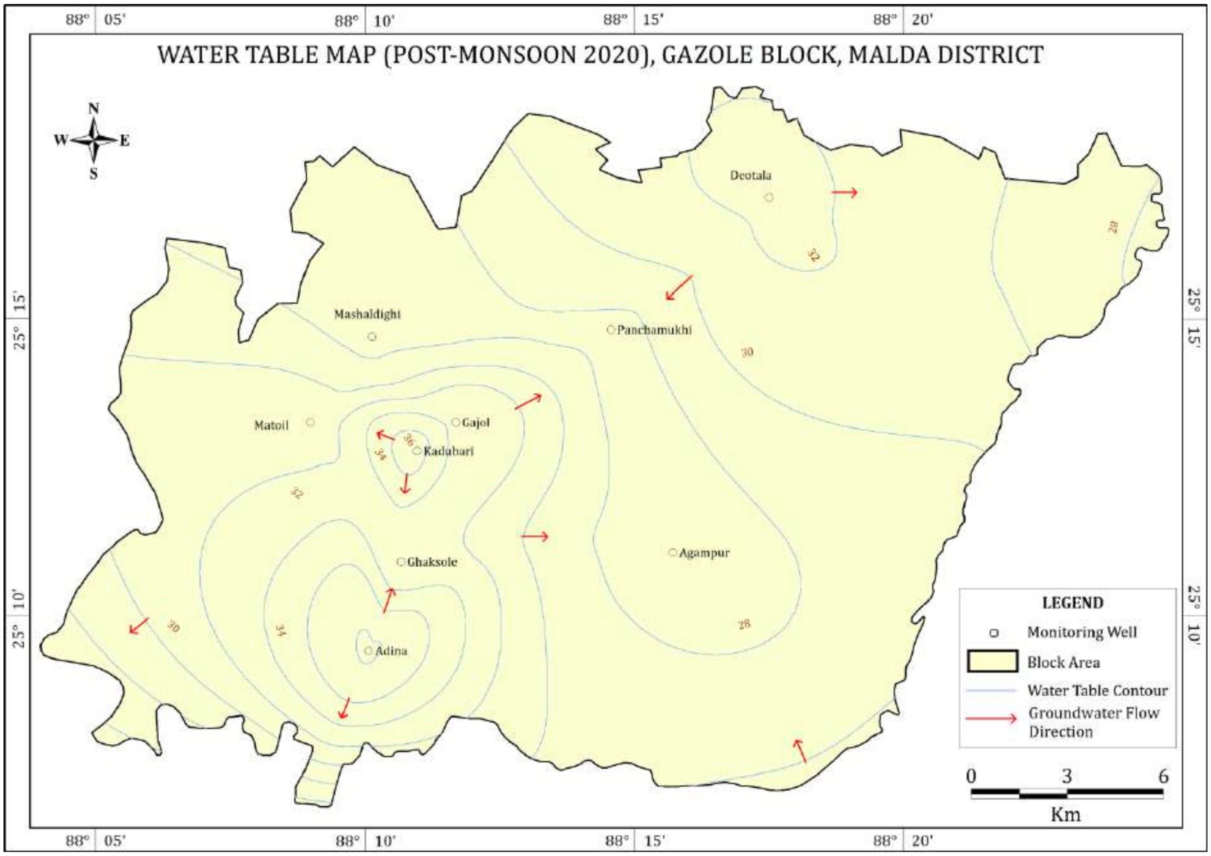


Fig. 6.30 Water table map (post-monsoon 2020), Gazole block

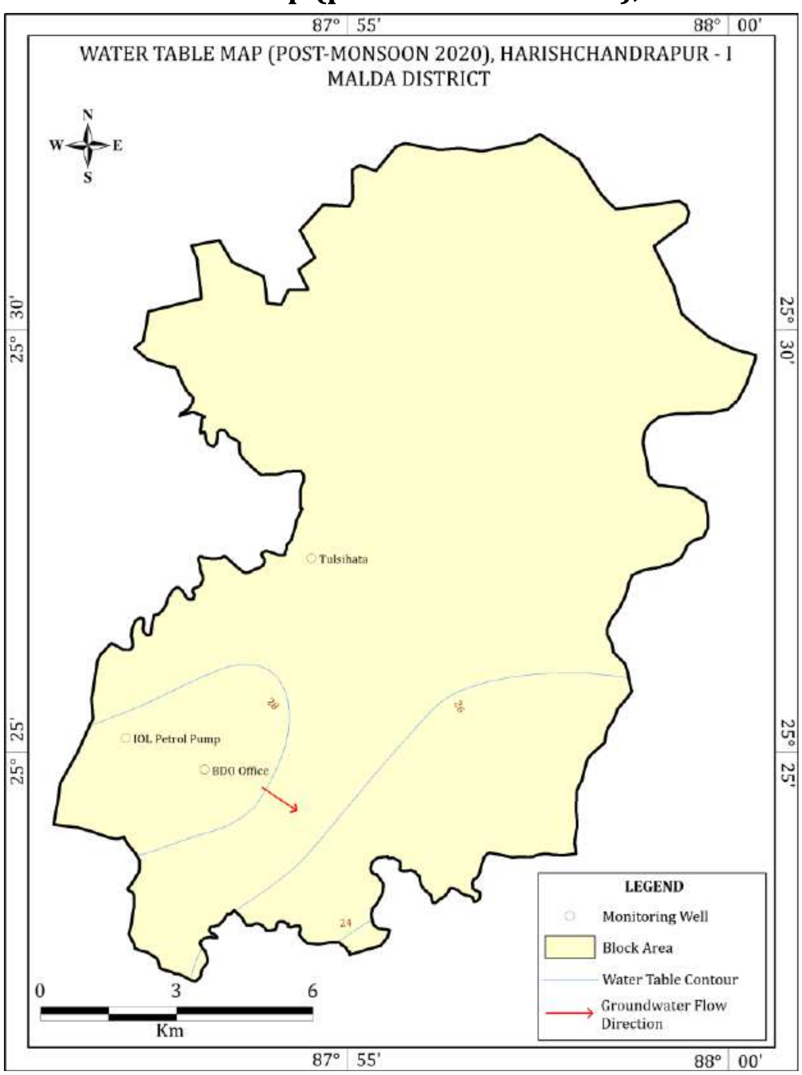


Fig. 6.31 Water table map (post-monsoon 2020), Harishchandrapur-I block

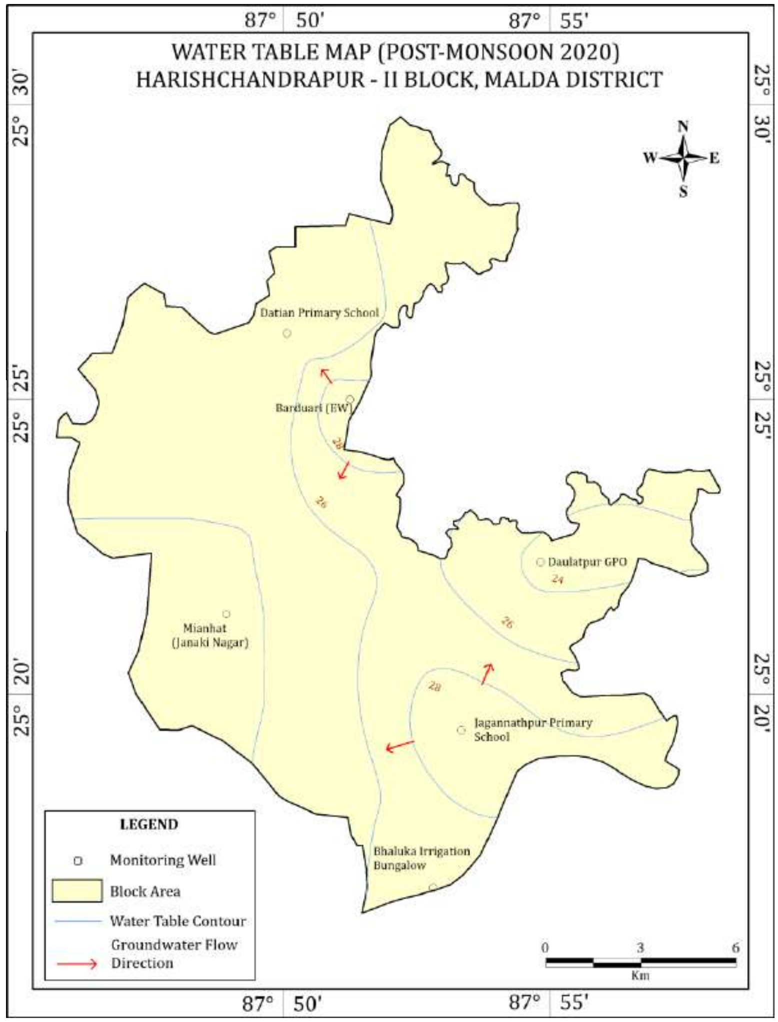


Fig. 6.32 Water table map (post-monsoon 2020), Harishchandrapur-II block

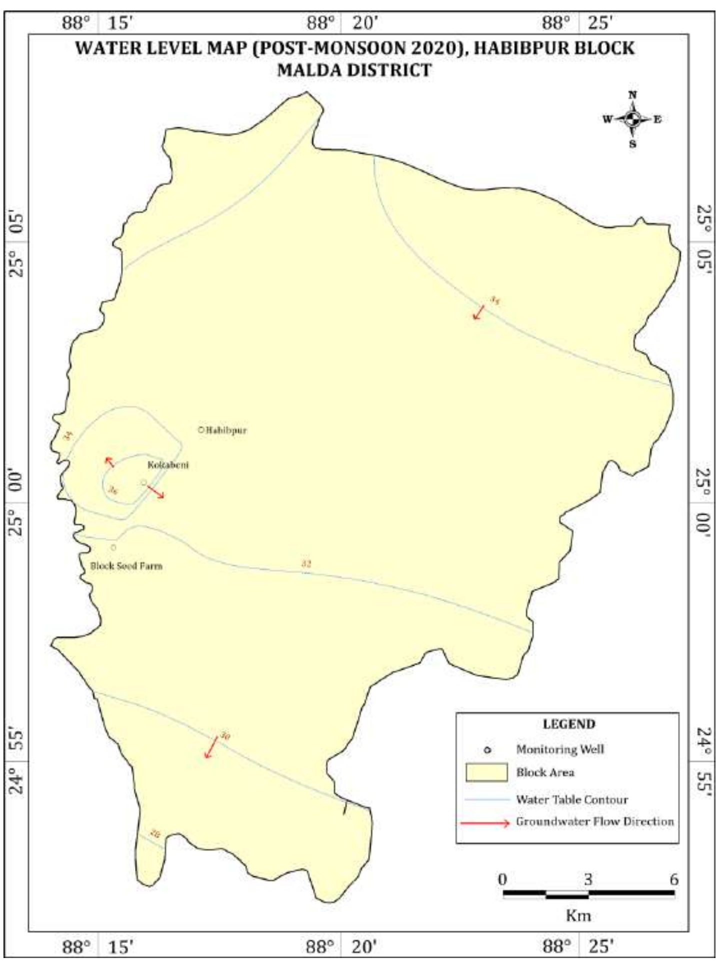


Fig. 6.33 Water table map (post-monsoon 2020), Habibpur block

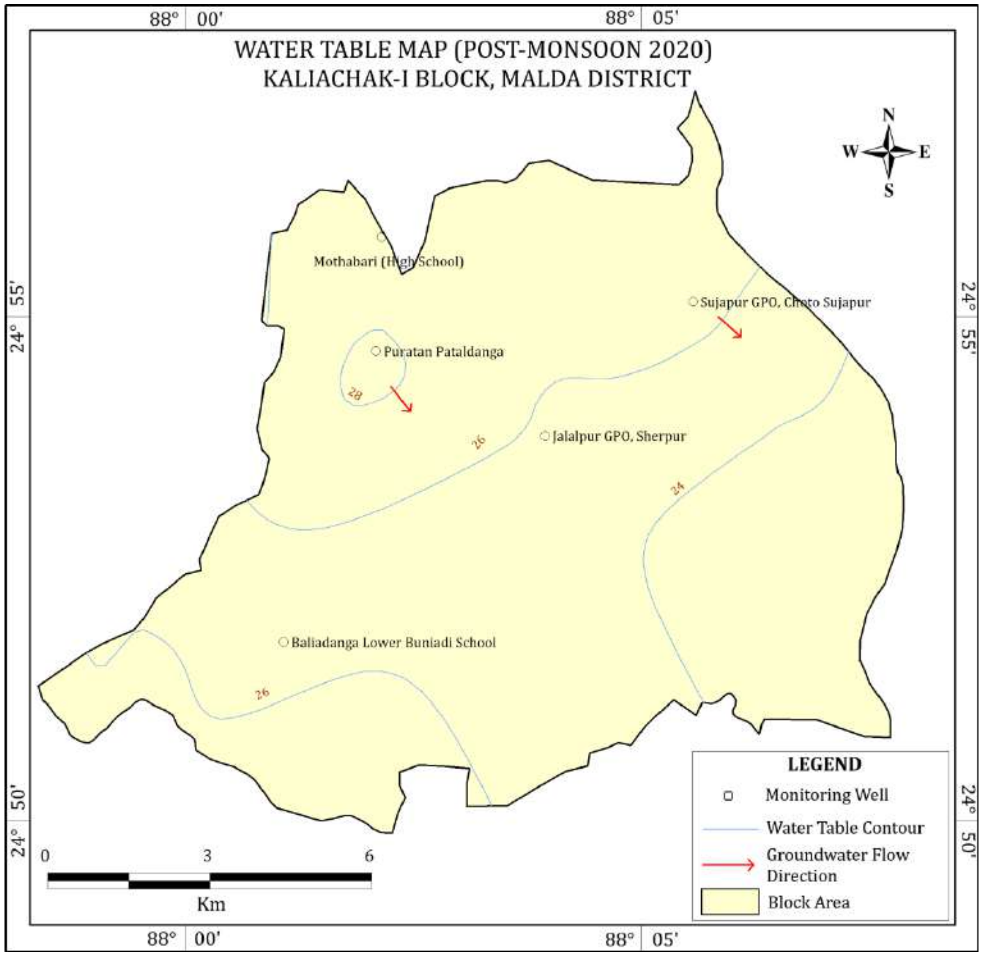


Fig. 6.34 Water table map (post-monsoon 2020), Kaliachak-I block

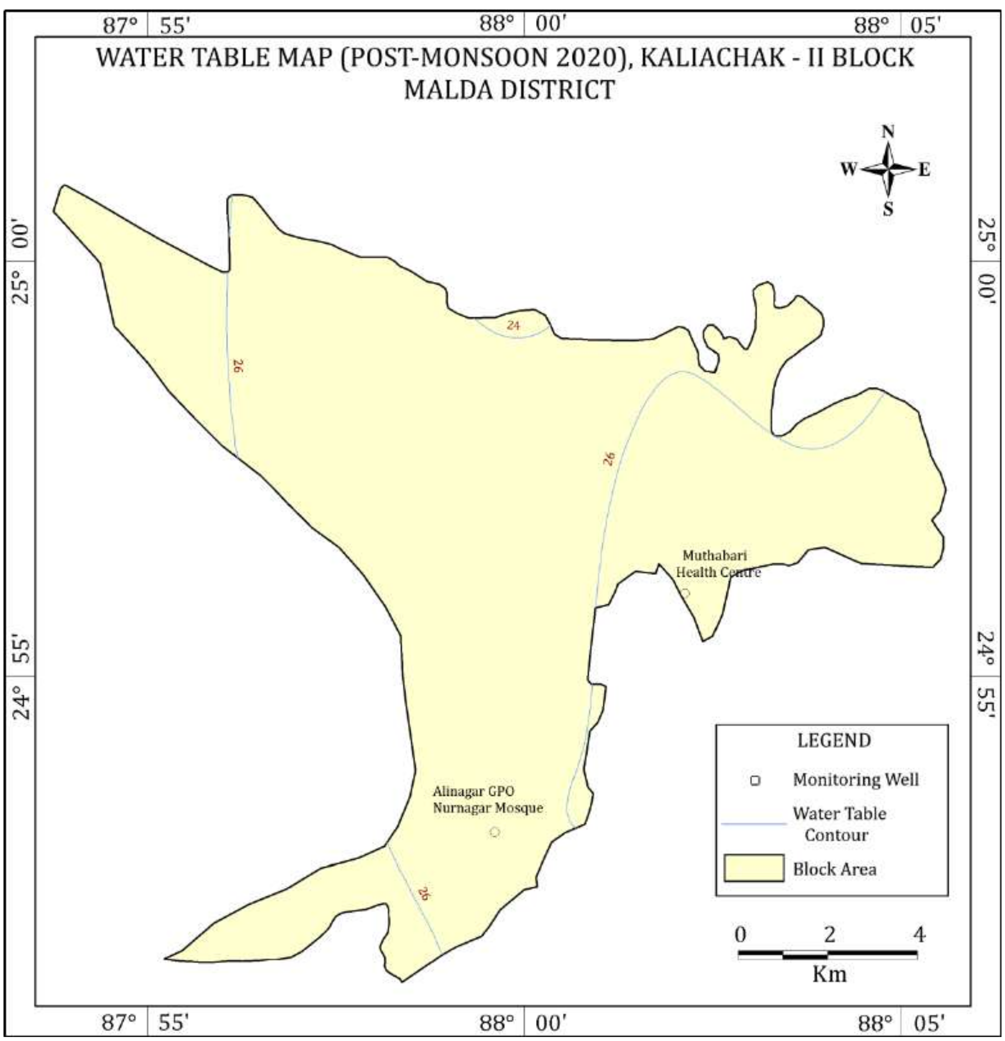


Fig. 6.35 Water table map (post-monsoon 2020), Kaliachak-II block

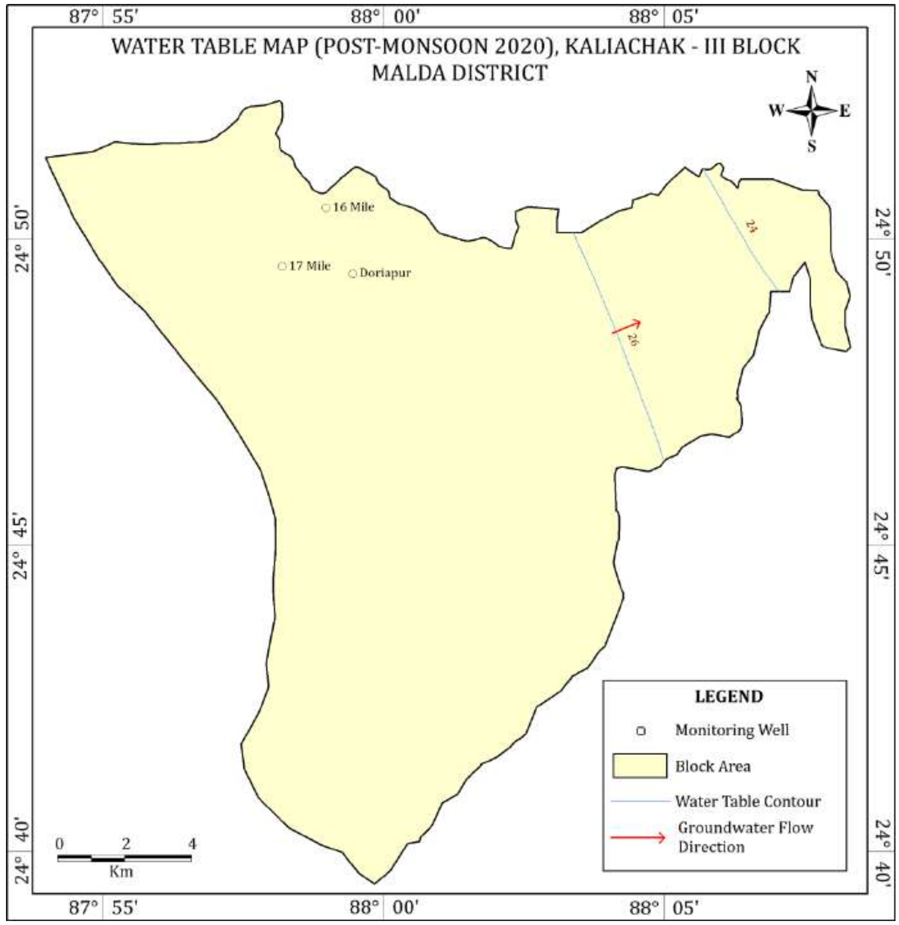


Fig. 6.36 Water table map (post-monsoon 2020), Kaliachak-III block

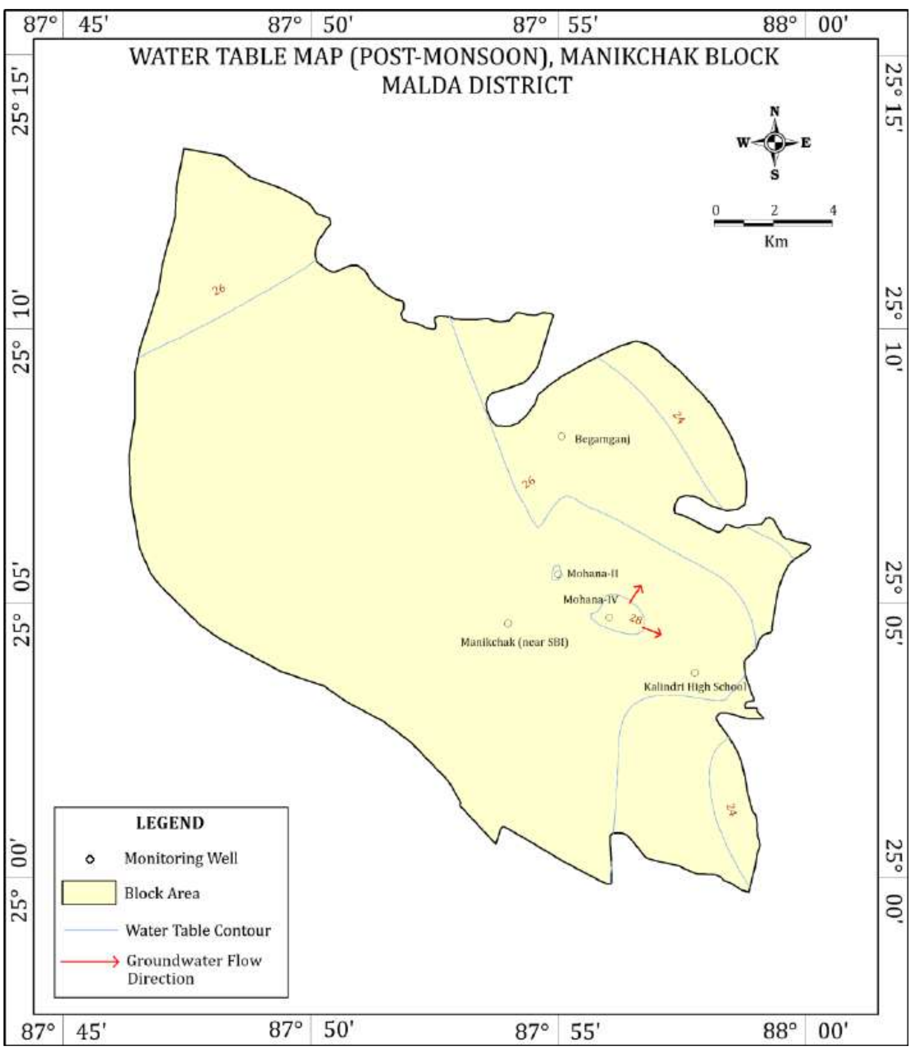


Fig. 6.37 Water table map (post-monsoon 2020), Manikchak block

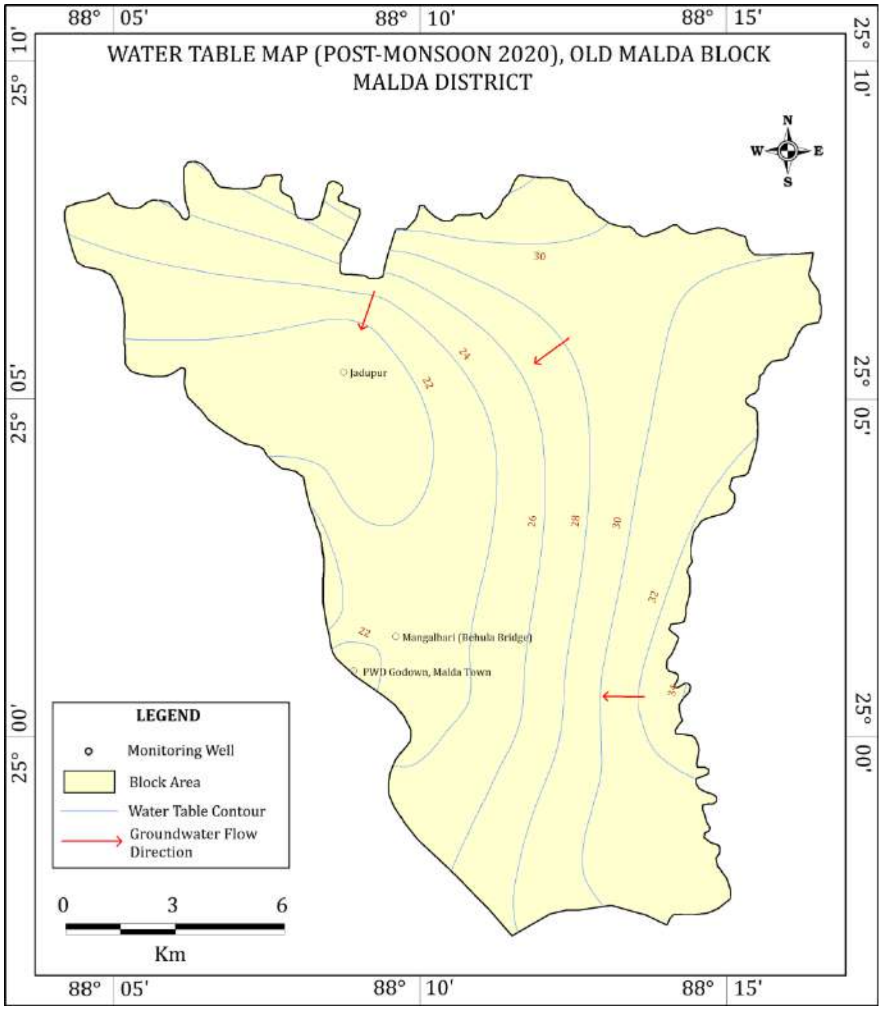


Fig. 6.38 Water table map (post-monsoon 2020), Old Malda block

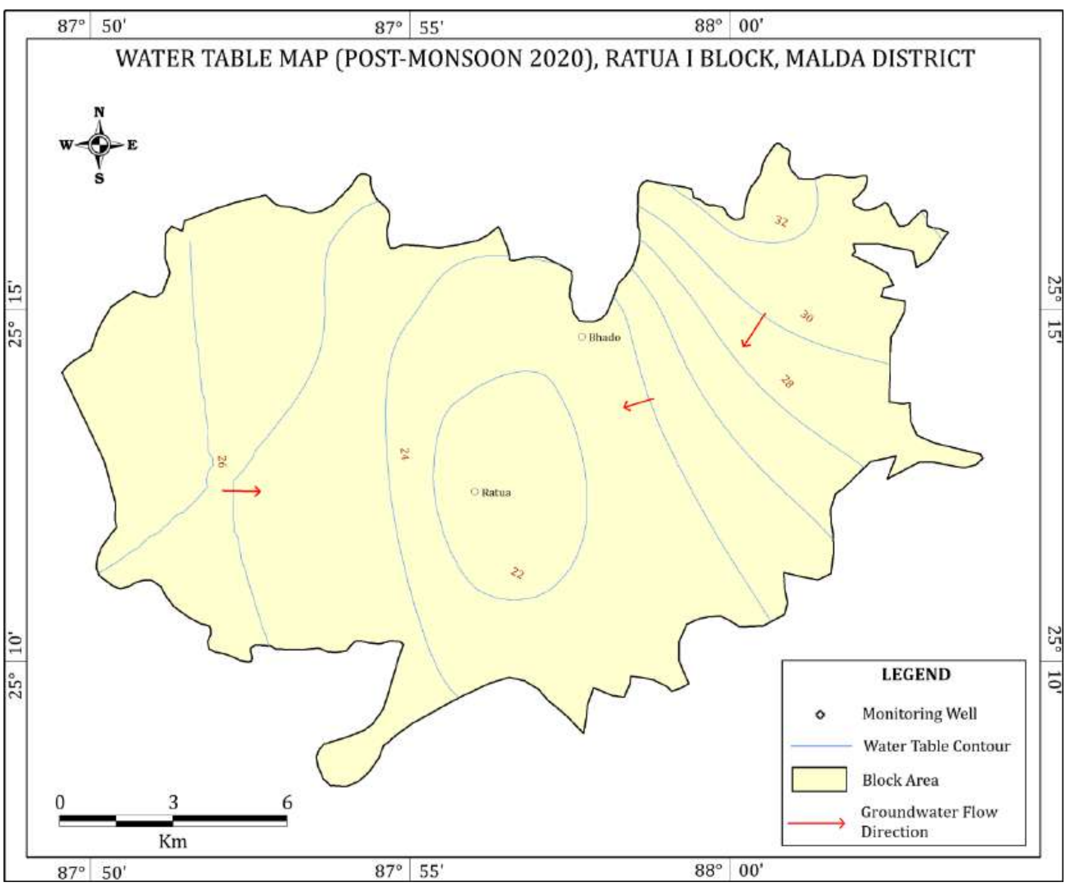


Fig. 6.39 Water table map (post-monsoon 2020), Ratua-I block

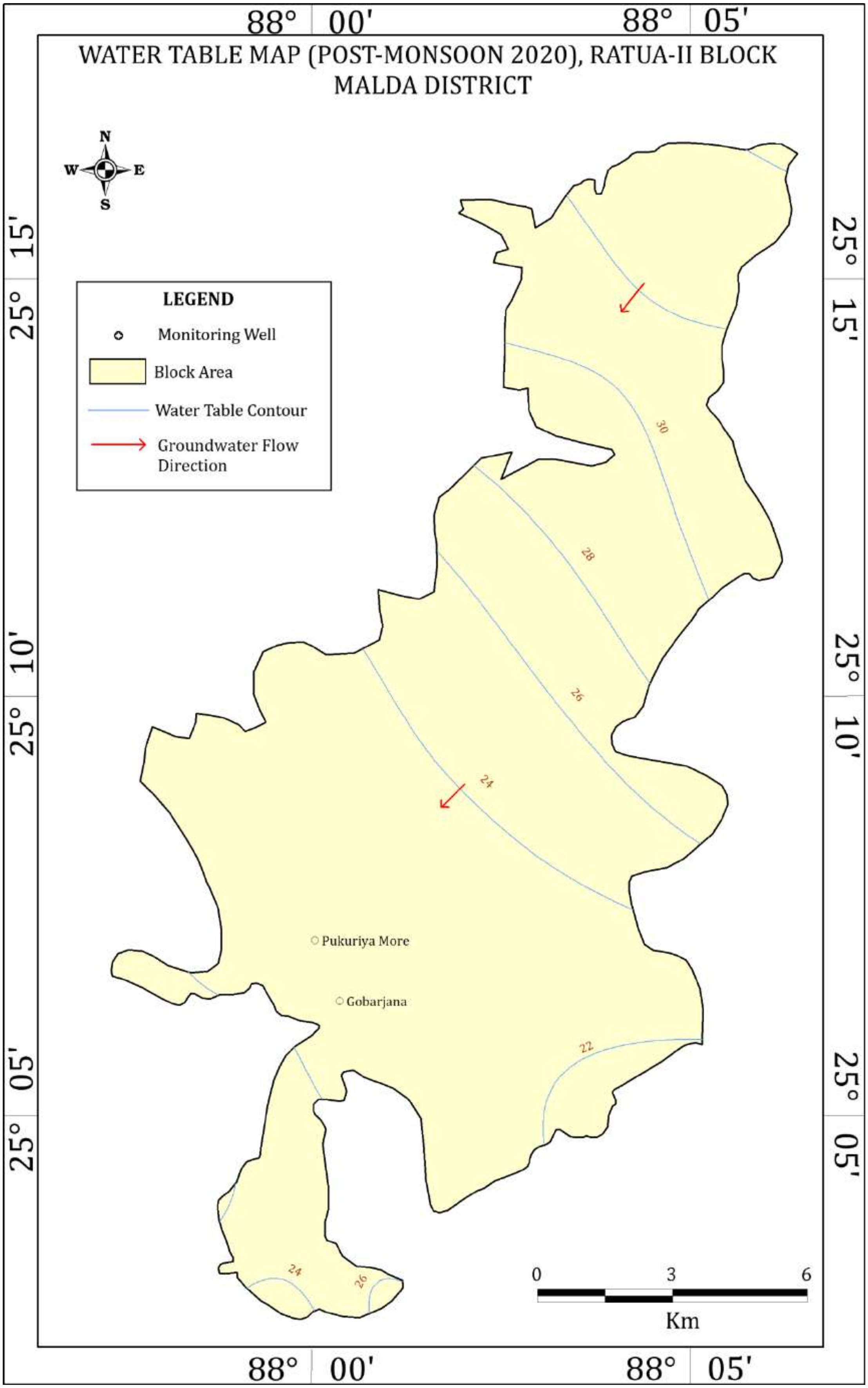


Fig. 6.40 Water table map (post-monsoon 2020), Ratua-II block

7. HYDROCHEMISTRY

7.1 Groundwater quality in shallow aquifers

A part of Malda district is affected by arsenic contamination in groundwater while another part is affected by fluoride contamination. Groundwater occurring in depth range of ~20 to ~95 m is affected by high arsenic in eight blocks viz. English Bazar, Manikchak, Ratua-I, Ratua-II, Chanchal-II, Kaliachak–I, Kaliachak-II and Kaliachak-III. Fluoride contamination in groundwater has been reported from Ratua-II and Bamongola blocks, which has been documented by the Fluoride Task Force, Government of West Bengal. High iron in groundwater has been reported from several locations in tube well water samples. Due to oxidation and co-precipitation of iron from ferrous to ferric state, dug well water is devoid of high iron. However, one growing concern is the rapid decline in the number of active dug wells over the last decade. Available data has revealed that groundwater in shallow aquifers is mildly alkaline and classified as Ca-HCO_3 type based on hydrochemical analysis.

Groundwater samples were collected from the monitoring wells tapping the shallow aquifer during pre-monsoon period in 2019 and 2020. Basic analysis and heavy metal analysis was done in the NABL accredited lab of CGWB, ER, Kolkata. The objective of the analysis was to determine the type of groundwater and to assess the extent of groundwater contamination, especially with reference to arsenic and fluoride. The results of chemical analysis reveal that generally groundwater is suitable for domestic and irrigational use, except for high arsenic, fluoride and iron in parts of the district.

During the present study, fifty-two samples were collected from the ground water monitoring wells and key observation wells (year: 2019 and 2020). The analysis result has shown arsenic concentration above the Permissible Limit (0.01 mg/L or 10 µg/L) in few locations like Pagla Bridge in Kaliachak-III block (129.10 µg/L), Thakurbari in Kaliachak-I block (76.73 µg/L) and Mothabari in Kaliachak-II block (33.94 µg/L). Highest fluoride concentration of 4.54 mg/L was observed in a tube well at Sripur in Ratua-II block, which is much beyond the acceptable limit of 1.50 mg/L for fluoride. Iron concentration above the desirable limit (1.0 mg/L) was recorded in tube wells at Pandua (2.03 mg/L) and at Pagla Bridge (1.85 mg/L). High iron in groundwater is evident by the bittersweet astringent taste and reddish-brown coloured stain in the utensils. However, iron can be removed relatively easily by keeping the water overnight and then filtration using locally available cloth. Although arsenic has a strong geochemical affinity with iron, the extent of arsenic contamination in remaining seven blocks is to be deciphered through periodic analysis, both during pre-monsoon and post-monsoon. Uranium above permissible limit (30 µg/L) was found in a single water sample collected from a tube well near Rathbari More, Malda City. However, as the concentration (34 µg/L) only marginally exceeds the permissible limit, more detailed sampling and analysis are required in future.

Range of various major constituents in groundwater in the shallow aquifers of Malda district is given in **Table 7.1.**

Table 7.1 General range of chemical parameters in shallow aquifers, Malda district

Constituents	Range	Constituents	Range
pH	7.4 - 8.2	K	BDL – 43 mg/L
EC	194 – 2900 µS/cm	HCO_3	67 – 958 mg/L
Fe	0.01 – 2.25 mg/L	SO_4	BDL – 123 mg/L
Ca	4 – 188 mg/L	Cl	14 – 978 mg/L
Mg	2 – 89 mg/L	F	BDL – 4.54 mg/L
Na	7 – 1193 mg/L	PO_4	BDL – 0.71 mg/L

BDL: Below Detection Limit

7.2 Groundwater quality in deeper aquifers

In the deeper aquifers (depth >60 m), arsenic in groundwater was detected from piped water supply schemes (at pump houses) by the Public Health Engineering Directorate (PHED), Govt. of West Bengal. The latest data collected in the year 2019 and 2020 from PHED, Malda Division and from PHED, Arsenic Area Water Supply Division at Laxmipur, has shown occurrence of arsenic in six blocks viz. Chanchal-I, Chanchal-II, Ratua-I, Ratua-II, English Bazar and Manikchak. Apart from arsenic, parameters like pH, turbidity, iron, manganese, Total Hardness and fluoride are also obtained from PHED, Malda Division. The block wise details on chemical analysis in piped water supply schemes are given in **Table 7.2.**

Table 7.2 Chemical quality of raw water before distribution through piped water supply schemes, Malda district

Block	Scheme Name	Tube Well No.	Date of testing	Chemical Parameters						
				pH	Turbidity (mg/L)	Iron (mg/L)	Manganese (mg/L)	Total Hardness (mg/L)	Total Arsenic (mg/L)	Fluoride (mg/L)
English Bazar	Sailpur W/S Scheme	TW-I	18-8-2020	7.12	2.16	0.93	0.11	304	0.0098	0.30
		TW-II	18-8-2020	7.11	1.24	0.72	0.07	300	0.0059	0.29
	Jotgopal (Mini) W/S Scheme	TW-I	18-8-2020	7.08	2.64	1.36	0.32	324	BDL	0.33

Manikchak	Uttar Chandipur W/S Scheme	TW-I	08-8-2019	7.38	3.16	2.90	0.16	344	0.053	--
		TW-II	08-8-2019	7.28	7.86	3.35	0.005	328	0.051	--
Chanchal-I	Dhanjana W/S Scheme	TW-I	14-1-2020	7.08	0.88	0.072	0.098	208	BDL	--
	Khanpur-Hulaspur W/S Scheme	TW-I	15-1-2020	7.04	0.60	0.036	0.014	204	BDL	--
Chanchal-II	Jalalpur W/S Scheme	TW-I	11-8-2020	7.10	1.26	0.521	0.014	196	BDL	--
	Gourhanda W/S -- Scheme	TW-I	17-8-2020	7.22	2.14	0.342	BDL	160	BDL	--
Ratua-I	Baharal Jalalpur W/S Scheme	TW-I	28-8-2020	6.92	3.67	0.956	0.233	260	0.004	--
	Samsi Jalalpur W/S Scheme	TW-I	14-8-2020	7.28	2.53	0.456	0.042	180	BDL	--
Ratua-II	Araidanga W/S Scheme	TW-I	25-8-2020	8.00	4.26	0.17	0.06	336	0.012	--
		TW-II	25-8-2020	7.00	3.92	0.31	0.04	352	0.016	--
	Nasipur W/S Scheme	TW-I	29-8-2020	7.00	9.82	0.81	0.53	300	0.003	--
		TW-II	29-8-2020	7.00	9.15	0.68	0.39	268	BDL	--

Source: Office of the Executive Engineer, PHED, Malda Division

A perusal of the above table indicates that generally groundwater in deeper aquifers is potable, except for high iron concentrations at Daulatpur (3.06 mg/L), Harishankarpur (2.07 mg/L), Jotgopal Water Supply Scheme (1.36 mg/L) and Uttar Chandipur Water Supply Scheme (2.90 mg/L and 3.35 mg/L). Arsenic concentration above the Maximum Permissible Limit (0.01 mg/L or 10 µg/L) was observed in Uttar Chandipur Water Supply Scheme in

Manikchak block having concentrations of 0.053 mg/L and 0.051 mg/L. high total Hardness (TH) was also seen in the raw water for distribution through the water supply schemes in English Bazar block (TH varying from 300 to 324 mg/L), Chanchal-I block (TH of 204 and 208 mg/L), Ratua-I block (TH of 260 mg/L), Ratua-II block (TH varying from 268 mg/L to 352 mg/L) and Manikchak block (TH of 328 and 344 mg/L).

To remedy the problem of high arsenic, it is recommended to install Arsenic Removal Plants on priority. Another alternative is to adopt conjunctive use of surface water and groundwater or commissioning of exclusively surface water based water supply from perennial rivers like Mahananda, Tangon, Fulahar and Nagri. Based on detailed chemical analysis, the parameter wise tabular data is presented in **Table 7.3.**

The major ion compositions of groundwater samples in Malda district do not vary much. Based on concentration of major cations and anions in 53 groundwater samples, a Piper Trilinear Diagram and Modified Piper Diagram (Chadha Diagram) are prepared, which is shown in **Fig. 7.1.**

The Piper Trilinear Diagram (Fig. 7.1.A) reveals that groundwater is generally rich in Mg^{2+} and/or Ca^{2+} ions (85% of samples) with bicarbonate (HCO_3^-) as a dominant anion (89% of samples). The diagram also shows that as per cationic concentration, groundwater chemistry was mainly characterized by prevalence of calcium, magnesium and bicarbonate ions, whether in dug well or in tube well samples. Groundwater is classified mainly as either sodium bicarbonate type or as magnesium bicarbonate type with very few samples (5 out of 53 or 9.43%) falling in mixed class.

Modified Piper diagram or Chadha diagram (Fig. 7.1B) reveals that 90% groundwater samples are either classified as calcium-magnesium-bicarbonate type or calcium-magnesium-chloride type with similar ionic compositions, which indicates rapid and frequent water-rock exchange and absence of delayed recharge in the area. Most of the samples are originated from shallow aquifers that are characterized by rainfall recharge. It is also inferred that weathering and solution are the major physico-chemical processes involved in the characterization of groundwater in Malda district. Groundwater is fresh and potable as it is either calcium bicarbonate or magnesium bicarbonate type of water. The low sodium and chloride content in groundwater indicates absence of inland salinity hazard. Thus, groundwater is also suitable for agri-irrigational use.

Table 7.3: Summary table on quality of groundwater, Malda District

Constituents		Total Sample Analysed	Malda District			IS 10500:2012		No. of Samples beyond Acceptable Limit	Samples beyond Acceptable Limit (%)	No. of Samples beyond Permissible Limit	Samples beyond Permissible Limit (%)
			Min	Max	Average	Acceptable Limit	Permissible Limit				
pH			7.12	8.45	7.90 ± 0.30	6.5-8.5	6.5-8.5	-	-	-	-
EC (μs/cm) 25^0C			153	1915	773 ± 429	-	-	-	-	-	-
TDS			134	986	447 ± 221	500	2000	18	34	-	-
Carbonate alkalinity as $CaCO_3$			-	-	-	-	-	-	-	-	-
Bicarbonate alkalinity as $CaCO_3$			70	695	299 ± 146	-	-	-	-	-	-
Total alkalinity as $CaCO_3$			57	570	245 ± 120	200	600	32	60	-	-
Chloride			7	310	86 ± 73	250	1000	01	02	-	-
Sulphate			Traces	154	18 ± 34	200	400	-	-	-	-
Nitrate		53	Traces	135	6 ± 19	45	45	01	02	01	02
Fluoride	mg/L (ppm)		Traces	1.48	0.65 ± 0.42	1.0	1.5	-	-	-	-
Calcium (as Ca)			8	208	49 ± 36	75	200	09	17	01	02
Magnesium (as Mg)			4	110	35 ± 21	30	100	26	49	01	02
Total Hardness (as $CaCO_3$)			42	571	248 ± 134	200	600	28	53	-	-
Sodium			5	115	51 ± 28	-	-	-	-	-	-
Potassium			0.3	90.5	14.9 ± 21.5	-	-	-	-	-	-
Uranium			Traces	0.015	0.004 ± 0.005	0.03	0.03	-	-	-	-
Iron			Traces	6.58	0.98 ± 1.54	1.0	1.0	10	19	10	19
Arsenic		159	Traces	0.40	0.02 ± 0.06	0.01	0.01	47	29	47	29

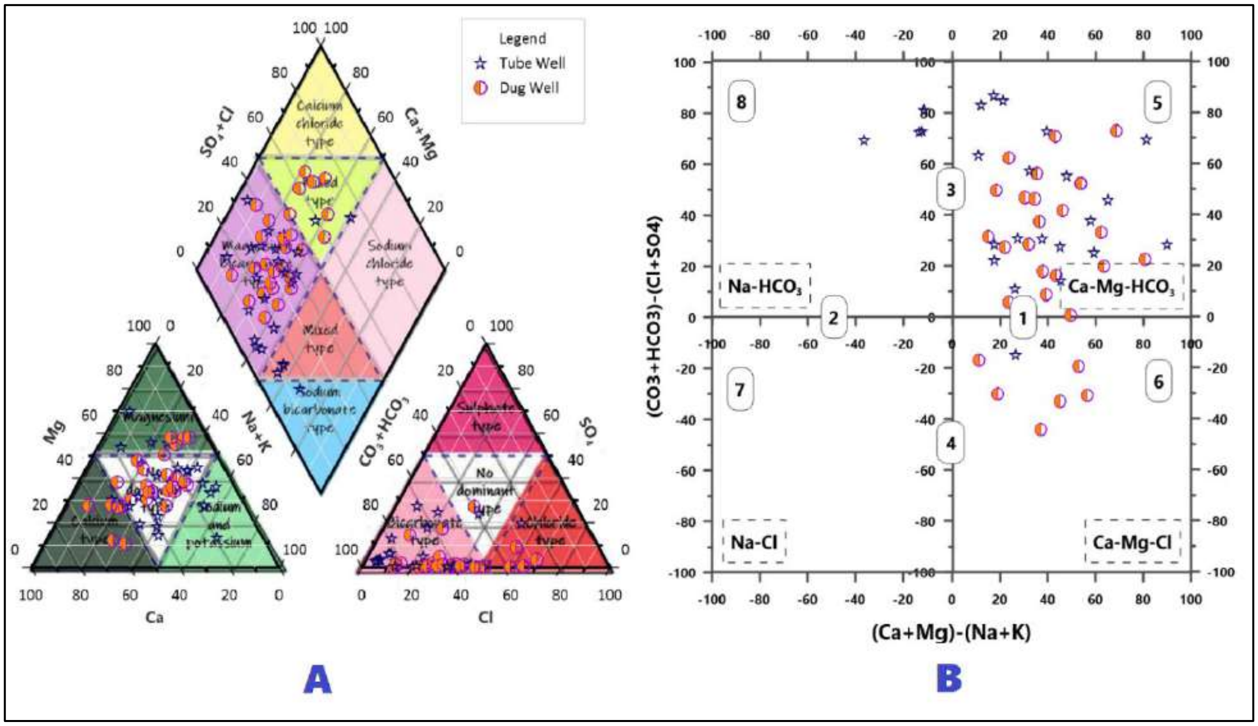


Fig. 7.1 Samples of aquifer mapping study (Malda district), plotted in Piper Trilinear Diagram (A) and Modified Piper Diagram (B)

The Gibbs Plot of groundwater samples of Malda district is shown in **Fig. 7.2.** It has been evident from the distribution of samples in the Gibbs Plot that chemical composition of groundwater is mainly affected by rock-water interaction and the processes of evaporation and sedimentation. Most of the groundwater samples are obtained from areas with ratios of $Na^+/(Na^++Ca^{2+})$ or $Cl^-/(Cl^-+HCO_3^-)$ less than 0.5 signifies the dominance of rock-water interactions and chemical weathering of rock forming minerals. Samples with $Na^+/(Na^++Ca^{2+})$ or $Cl^-/(Cl^-+HCO_3^-)$ ratios greater than 0.5 and TDS levels between 134 – 986 mg l^{-1} shows that the groundwater chemistry has been controlled not only by rock weathering interaction but also by evaporation precipitation at places.

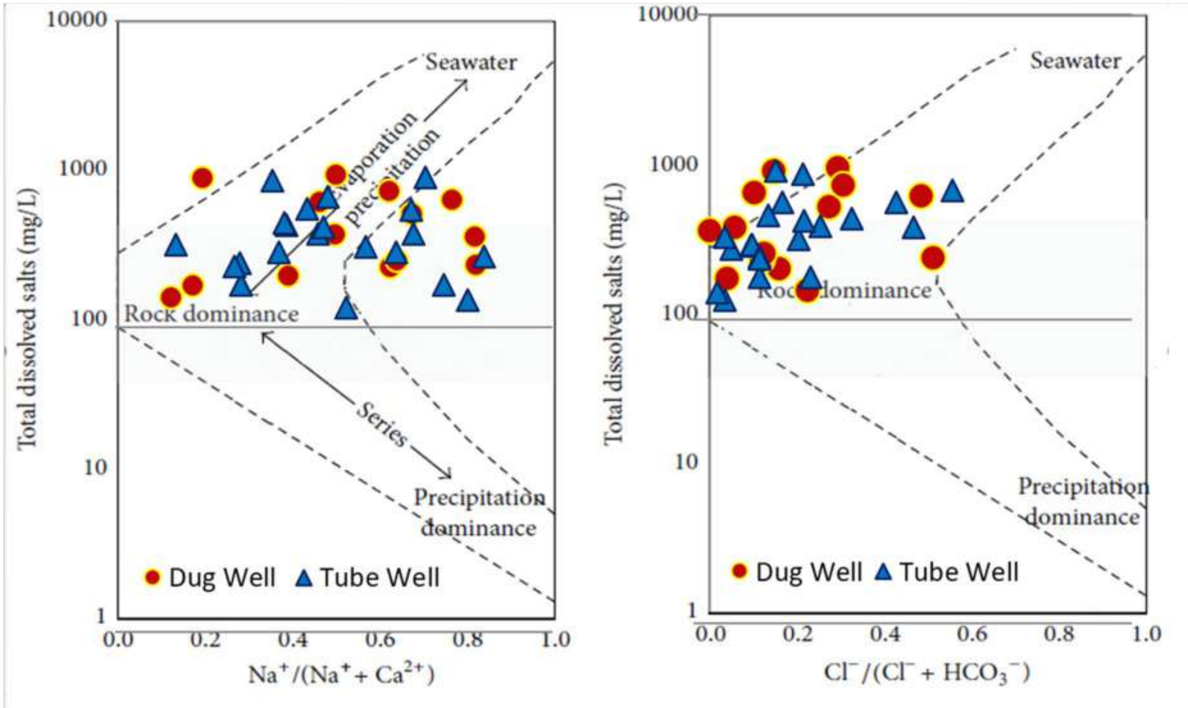


Fig. 7.2 Gibbs Diagram of groundwater samples, Malda District

7.3 Suitability of groundwater for irrigation

Groundwater suitability for irrigation in Malda district can be best explained with the help of Wilcox Diagram and classification scheme invented by United States Salinity Lab (USSL). The USSL diagram and Wilcox plot best explains the combined effect of sodium hazard (S) and salinity hazard (C). The Wilcox and USSL Diagrams are shown in **Fig. 7.3.** Analysis of the figure reveals that a majority of the groundwater samples collected from Malda district falls in S1-C2 and S1-C3 class that are generally suitable for irrigation. Considering the pH, EC, Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Total Hardness (TH), the Wilcox Diagram and USSL Diagram both reveals that groundwater in Malda district is suitable for agri-irrigational use.

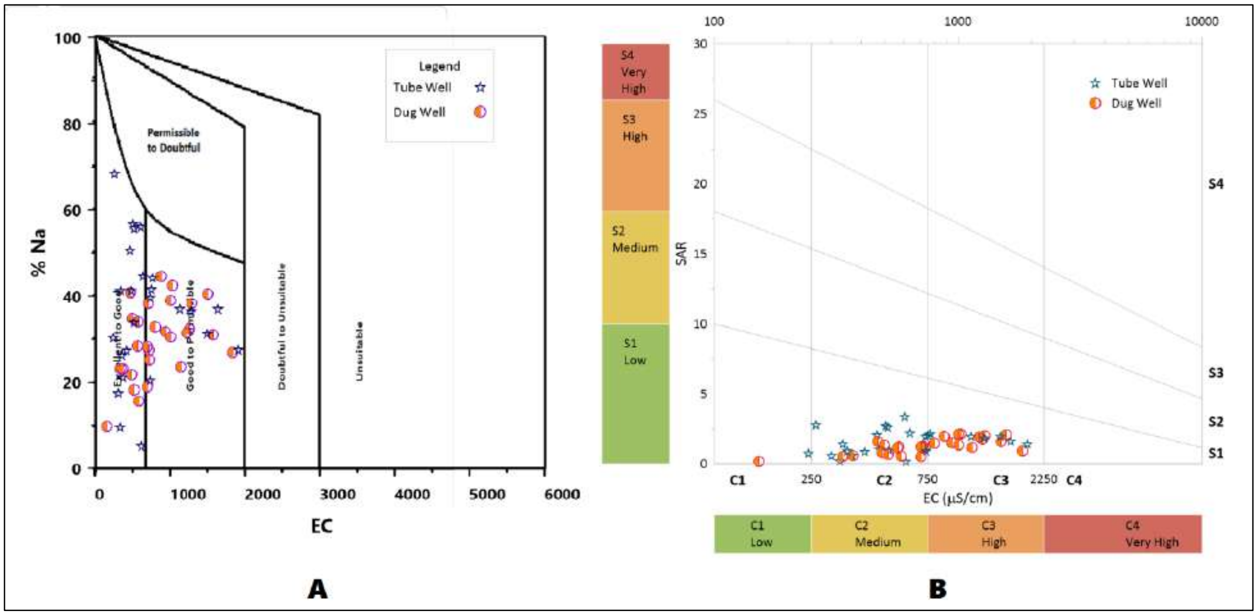


Fig. 7.3 Suitability of groundwater for irrigation use, Malda district; shown in (A) Wilcox Diagram and (B) US Salinity Diagram

A summary table for high arsenic (As) in groundwater of Malda district, as per in house data of 159 samples analyzed for arsenic in groundwater, is given below.

No. of Block from which As> 0.01 mg/L has been reported	10
Total no. of Sample Analysed	159
Samples with As concentration> 0.01 mg/L	47
% of sample having As concentration> 0.01 mg/L	29.0%
Highest concentration reported (mg/L)	0.402
Block	Kaliachak-I
Location	Sujapur

A summary of the major findings of the hydrochemical scenario of Malda district is given below.

- According to Arsenic Task Force, Government of West Bengal, eight blocks of Malda District *viz.* English Bazar, Kaliachak-I, Kaliachak-II, Kaliachak-III, Manikchak, Ratua-I, Ratua-II and Chanchal-II have been identified as arsenic affected blocks. In addition, as per CGWB analysis, elevated level of arsenic in groundwater has been detected in three additional blocks – Gazole, Harischandrapur-I and Old Malda. Further studies are required to confirm the findings.

- As per the database of Fluoride Task Force, Government of West Bengal, two blocks have been identified as fluoride contaminated *viz.* Bamongola and Ratua-II. Available data of Public Health Engineering Directorate, Malda Division has indicated sporadically high fluoride in groundwater in Old Malda block, although CGWB analysis has not revealed high fluoride in Old Malda block.
- Occurrences of iron exceeding the permissible limit of 1.0 mg/L were found in few locations of Bamongola, English Bazar, Gazole, Kaliachak-III and Manikchak block. Due to unpleasant taste of iron-rich groundwater, villagers rarely use the source for drinking. However, iron contaminated groundwater has been found to be occasionally used for domestic use due to absence of suitable alternate source.
- It has also been observed that groundwater of shallow tube wells are usually contaminated with arsenic and iron, whereas dug wells do not show any contamination as such. This is due to oxygen rich environment in the open dug wells, which results in oxidation of ferrous iron into ferric iron (Fe^{+3}) and trivalent arsenic to much less toxic pentavalent arsenic (As^{+5}) and their removal from the dissolved state into precipitates.
- In respect of suitability assessment for irrigational use, groundwater in Malda district was mostly found suitable for irrigational use as majority of the samples either belong to S1-C2 or S1-C3 class.
- Facies classification of groundwater in Malda district has shown that maximum number of groundwater samples belong to Ca^{2+}-Mg^{2+}-HCO_3^- type (90% of the total number of sample analyzed), which indicates rapid and frequent water-rock exchange and recharge of phreatic and shallow aquifer with recent fresh water in the Gangetic Alluvial Plain in Malda district.

8. AQUIFER MANAGEMENT PLAN

8.1 Groundwater related issues and problems

Some of the groundwater related issues and problems in Malda district are given below:

- Arsenic beyond Permissible Limit (>0.01 mg/L or 10 µg/L) is reported in eight blocks: English Bazar, Manikchak, Kaliachak-I, Kaliachak-II, Kaliachak-III, Ratua-I, Ratua-II and Chanchal-II. According to the report of Arsenic Task Force (Govt. of West Bengal), 1983601 people including rural population of 1794550 and urban population of 189051 are affected by arsenic toxicity. A total of 1146 habitations in eight blocks of the district are affected by arsenic contamination (Talukdar and Bandopadhyay 2017).
- Water supply tube wells of Public Health Engineering Directorate (PHED) are mainly confined to shallow or moderately deep aquifers (from 45 to 100 m), resulting in high arsenic in groundwater. Thus, surface water based schemes are exclusively used for water supply in arsenic affected blocks.
- Bamongola and Ratua-II blocks are reported to be affected by fluoride contamination in groundwater (fluoride >1.5 mg/L) affecting a rural population of 2110 (Fluoride Task Force and PHED, Govt. of West Bengal). Analysis by CGWB has shown fluoride concentration of 1.5 mg/L at Peerganj in Ratua-II block. Latest data of PHED (Pers. Comm.) has shown fluoride of 2.07 mg/L at Samsabad in Old Malda block.
- Iron contamination in groundwater was observed at Pandua in Gazole block and Pagla Bridge in Kaliachak-III block. Historical data has revealed sporadic iron contamination in Kaliachak-I, II and III, Chanchal-I and II, Ratua-I and II, Harishchandrapur-I and II, English Bazar, Old Malda and Manikchak block.
- High groundwater abstraction through irrigational tube wells may lead to downward migration of arsenic rich water used for agriculture, which could eventually lead to horizontal movement of arsenic contaminated groundwater into arsenic free aquifers (Aquifer-1A) at shallow to moderately deep levels. This may lead to arsenic contamination in previously uncontaminated aquifers (Sikdar and Chakraborty 2007).
- Soil acidity and soil erosion are observed in Kaliachak-II and III, Manikchak, English Bazar, Harishchandrapur-I and II block. Large residential and cultivated areas and several hectares of mango orchards are affected by soil erosion and collapse of riverbanks of Ganga and Fulahar rivers. Indiscriminate use of chemical fertilizers for achieving higher crop yields has increased the acidity of top soil in Ratua-I and Ratua-II blocks, which may result in diminished agricultural production.
- Water logging during monsoon and post-monsoon are observed in low lying *Taal* and *Diara* areas in Harishchandrapur-I and II, Manikchak, Kaliachak-II and Ratua-I blocks,

with high rate of deposition of sand and silt. This reduces rate of infiltration and downward percolation, resulting in less groundwater recharge.

8.2 Supply side and demand side aquifer management

For an effective and efficient management of the groundwater resources, formulation of an Aquifer Management Plan (AMP) at district and block level is very important. A sustainable management of aquifers will depend on total available groundwater resources, present status of groundwater development and groundwater quality issues, if any. Supply side management of an Aquifer Management Plan (AMP) focuses on increasing the volume of water available through ways like a) finding new resources, b) increasing storage capacity, c) diverting water to increase water supply at a particular location and d) using technology to create clean, potable water from a previously unutilized source. Demand side management, on the other hand, can be defined as reducing the volume of water that is being used by the stakeholders for specific purpose like household use, farming, municipal or industrial needs. The main objective is to increase the Water Use Efficiency throughout the year.

Due to low Stage of Groundwater Development (48.13%) in Malda district, there is no justification in implementing demand side management at district level. However, supply side management interventions may be adopted through implementation of water resources augmentation programmes like direct increase in storage potential through rain water harvesting or indirectly replenishing the shallow aquifers through artificial recharge in feasible areas. A detailed discussion on this aspect is given separately.

8.3 Aquifer Management Plan for drinking and domestic sector

The nodal agency for drinking and domestic water supply in rural and urban areas of Malda district is the Public Health Engineering Directorate (PHED), Government of West Bengal. Water supply schemes are implemented through PHED, Malda Division and PHED, Arsenic Area Water Supply Division. As on March 2020, total number of Piped Water Supply Schemes (PWSS) in Malda district was 120. Another 33 water supply schemes are being implemented under various projects by the PHED, Malda Division. Seven PWSS are awaiting sanction with a designed population of 31348 (District Survey Report, 2021). Two schemes covering Old Malda, Habibpur and Bamongola blocks are being implemented with funding through Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and *Pradhan Mantri Krishi Sinchai Yojana – Har Khet Ko Pani* (PMKSY-HKKP) project.

As on March 2021, there are 21200 functional tube wells in Malda district. Out of the total rural population, 63.11% is covered by the commissioned Piped Water Supply

Schemes (PWSS) maintained by the Public Health Engineering Directorate, Malda Division. Apart from this, 4.84% of the population is being covered under the ongoing PWSS. It is envisaged that after commissioning of all schemes, 71.06% of the rural population would have potable water supply. A project on implementation of 50 Dual Use Solar Pump Fitted Water Supply Scheme is under pipeline, which will cover Old Malda, Ratua-I, Gazole, Habibpur, Kaliachak-I, Kaliachak-II, Chanchal-I, Chanchal-II, Harishchandrapur-I and Harishchandrapur-II block (District Survey Report 2021). Two water supply schemes are presently operational in Malda Sadar Hospital and Chanchal Sadar Hospital by the PHED, Malda Division. A list of seventeen groundwater based water supply schemes commissioned under Master Plan by the PHED, Malda Division in English Bazar, Manikchak, Ratua-I and Ratua-II blocks is given in **Table 8.1.**

Table 8.1 Groundwater based water supply schemes commissioned in Malda district

Sl. No.	Name of Scheme	Block	Population benefited
1	Dakshin Chandipur	Manikchak	6092
2	Gopalpur	Manikchak	15477
3	Mahabbatpur	Manikchak	2643
4	Barachak	English Bazar	863
5	Itakhola	English Bazar	453
6	Jot Basanta	English Bazar	11076
7	Sahazalalpur	English Bazar	2790
8	Bhado	Ratua-I	16844
9	Bihari	Ratua-I	7559
10	Bijrabhita & its adjacent mouzas	Ratua-I	14799
11	Kankot	Ratua-I	9581
12	Mahammadpur	Ratua-I	2254
13	Mahespur	Ratua-I	1999
14	Gobarjana & its adjacent mouzas	Ratua-II	7230
15	Kadamtali & its adjacent mouzas	Ratua-II	10933
16	Magura	Ratua-II	15971
17	Pirpur	Ratua-II	1796

(Source: Master Plan, PHED, Govt. of West Bengal)

For arsenic removal in groundwater, five water supply schemes were made functional by the PHED, Arsenic Area Water Supply Division in Ratua-I and Ratua-II blocks. The schemes cater to a design population of 37710 with cumulative supply of 4112 m^3/day. Details of these schemes are given in **Table 8.2.**

Table 8.2 Details of schemes for arsenic removal in groundwater, Ratua-I and Ratua-II blocks, Malda district

Name of Scheme	Block	Capacity (m^3/hr)	Clear water supplied (m^3/day)	Design Population
Maheshpur Water Supply Scheme (WSS)	Ratua-I	12.0	192.0	2665
Bakhra WSS	Ratua-I	39.0	624.0	6306
Sultanpur WSS	Ratua-II	51.0	816.0	1847
Sambalpur WSS	Ratua-II	99.0	1584.0	17548
Pirpur WSS	Ratua-II	11.0	176.0	1847
	Total	212.0	3392.0	37710

(Source: Arsenic Area Water Supply Division, PHED)

The data in **Table 8.2** shows that the largest water supply scheme for arsenic-free drinking water is at Sambalpur having capacity of 1584 m^3/day catering to the requirement of a rural population of 17548. The water supply scheme at Pirpur has the lowest capacity (176 m^3/day) catering to the water requirement of 1847 people.

8.4 Aquifer Management Plan for irrigation sector

Due to extensive agricultural activities in Malda district, an unprecedented stress has been imposed on Aquifer-IA and Aquifer-IB. Cultivation of summer paddy (*Boro Dhaan*) has adversely affected available groundwater resources, which is being extracted through 33616 Shallow Tube Wells and 569 Deep Tube Wells as per 5th Minor Irrigation Census (Source: Statistical Handbook, 2014). Irrigation is dependent on surface storage also in the form of 255 tanks. In addition to this, 446 Surface Flow Schemes and 483 River Lift Irrigation (RLI) schemes are utilized to irrigate the total Cultivable Command Area (CCA) of 1277.83 km^2 Out of the total CCA, 956.30 km^2 was under groundwater irrigation and 364.56 km^2 under surface water irrigation. *Boro* paddy is cultivated primarily in low lying areas of *Barind Tract.* In Malda district, Irrigation Potential Created by groundwater resources is 1402.68 km^2, which is more than twice the potential created by surface water irrigation (622 km^2).

As the semi-confined and confined aquifers are already under stress, it is not recommended to install additional tube wells for irrigation. Instead, a modification in cropping pattern may be adopted depending on local socio-economic and cultural (psychological) conditions. Crop diversification technique is also recommended, keeping the fundamental crops unchanged. Less water intensive crops like sunflower (standing crop height: 350-500 mm), ginger (standing height: 350-400 mm) and beans (standing height: 300-400 mm) needs to be cultivated along with onion (standing height: 350-550 mm) and tobacco (standing height: 400-600 mm) simultaneously with reduction of cultivation of sugarcane, which is a highly water intensive crop with standing height ranging from 1500 to 2500 mm.

Sufficient number of irrigational tube wells is already operational in Malda district. Hence, there is very little justification to construct additional Medium Duty Tube Wells (MDTW) or Heavy Duty Tube Wells (HDTW) to increase irrigation efficiency. A much better way to optimize groundwater resources is to adopt crop diversification and modification in cropping pattern, keeping the fundamental crops (mainly paddy) unchanged. Summer paddy (*Boro Dhaan*) cultivation needs to be reduced at least by 10% of present production considering the adverse impact of lowering of groundwater level in the peak summer season. Cropping of novel varieties (peanuts, maize, soybean) and increasing the horticultural activity through cultivation of varieties like sunflower will result in increasing the water use efficiency.

8.5 Aquifer Management through Artificial Recharge and Rain Water Harvesting

Due to predominantly confined and semi-confined nature of aquifers in Malda district, the scope of artificial recharge is generally very less, except for Kaliachak-I, Old Malda and Gazole blocks. The details of priority areas identified for limited artificial recharge based on the unsaturated aquifer volume, has been enumerated under the latest Master Plan of Artificial Recharge (CGWB 2020). Rain water harvesting technique, especially roof top rain water harvesting in urban and peri-urban areas like Malda Town, Gazole, Habibpur, Chanchal, Harishchandrapur, Ratua and Manikchak is feasible. Open area rain water harvesting is suitable for rural areas. Normal Rainfall in Malda district is sufficiently high (1453 mm) to harness the potential of water conservation and management through conjunctive use of surface water and groundwater.

As per latest Master Plan on Artificial Recharge (CGWB 2020), only three blocks namely Kaliachak-I, Old Malda and Gazole are suitable for artificial recharge. The recharge structures should be constructed on priority in areas having post-monsoon depth to water level >9 m bgl. Details on surface water requirement and artificial recharge worthy areas are given in Table 8.3. A perusal of the table shows that the highest artificial recharge worthy area of 2.04131 km^2 is in Kaliachak-I block. This is followed successively by recharge worthy area of 0.25582 km^2 in Gazole block and 0.02194 km^2 in Bamongola block.

Out of the total mappable area under NAQUIM study (3733 km^2), only 2.32 km^2 (0.062% of total) is suitable for artificial recharge, out of which 2.04 km^2 is in Kaliachak-I block. Feasible recharge structures recommended are Percolation Tanks (PT), Re-excavation of Existing Tanks with Recharge Shafts (REET), and Injection Wells (IW).

Table 8.3 Details of Artificial Recharge in three blocks of Malda district

Block	Total utilizable volume of surface runoff (MCM)	Unsaturated aquifer volume for recharge (MCM)	Area suitable for Artificial Recharge (km^2)	Recharge structures recommended		
				Percolation Tank	Re-excavation of Existing Tank with Recharge Shaft	Injection Well
Kaliachak-I	0.685	12.248	2.041	One	One	One
Old Malda	0.007	0.132	0.022	--	--	--
Gazole	0.086	1.535	0.256	--	--	--
Total	**0.778**	**13.914**	**2.319**	**One**	**One**	**One**

*MCM: Million Cubic Metre

(Source: Master Plan for Artificial Recharge, CGWB 2020)

A perusal of Table 8.3 reveals that among all the blocks, Kaliachak-I has the highest potential for artificial recharge. Recharge potential for feasible structures are:

a) Percolation Tank: 0.343 MCM
b) Re-excavation of Existing Tanks with Recharge Shaft: 0.137 MCM
c) Injection Well: 0.206 MCM

Due to occurrence of Older Alluvium, feasibility of artificial recharge is very less both for semi-confined aquifers (tapped by MDTW) or the unconfined aquifers (tapped by Dug Wells). Hence, bulk of the non-committed surface run-off needs to be harnessed through water conservation structures like storage tank and traditional rain water harvesting through small pits and cement concrete tanks, depending on the socio-economic considerations at village or community level. There is an urgent need to involve Non-Government Organizations, Self Help Groups, Gram Sabha/Gram Panchayat and District Administration in a synergistic manner for effective implementation of participatory management at village and block level. Formulation and implementation of village level Aquifer Management Plan is possible through participatory groundwater management.

8.6 Non-committed surface runoff for artificial recharge and rain water harvesting

The volume of surface runoff that can be harvested without creating any adverse effect on the environment has been estimated. Parameters used for this estimation are the normal annual rainfall, geographical area, runoff co-efficient and soil type. The non-committed surface runoff after deducting the Environmental Flow (e flow) component is given in **Table 8.4.**

Table 8.4 Estimation of non-committed surface runoff for rain water harvesting, Malda district

Block	Area, A (km^2)	Normal Monsoon Rainfall, R_n (mm)	Volume of Monsoon Rainfall, V_{mr} $((A*R_n)*10^3)/10^6$ (MCM)	Runoff Coefficient, C (for land slope: 0-5%)	Total volume of surface runoff available annually, V_t (V_{mr}*C) in MCM	V = 0.75* V_t (MCM)	Non-Committed Surface Runoff, V_{nc} (0.5*V) in MCM	Non-Committed Surface Runoff after considering e-flow, V_f (0.6*V_{nc}) in MCM
Kaliachak-I	112.0	1453.0	162.74	0.50	81.37	61.03	30.52	18.31
Kaliachak-II	223.0	1453.0	324.02	0.50	162.01	121.51	60.76	36.46
Kaliachak-III	260.0	1453.0	377.78	0.50	188.89	141.67	70.84	42.50
English Bazar	242.0	1453.0	351.63	0.50	175.82	131.87	65.94	39.56
Bamongola	206.0	1453.0	299.32	0.50	149.66	112.25	56.13	33.68
Habibpur	396.0	1453.0	575.39	0.50	287.70	215.78	107.89	64.73
Manikchak	325.0	1453.0	472.23	0.50	236.12	177.09	88.55	53.13
Old Malda	217.0	1453.0	315.30	0.50	157.65	118.24	59.12	35.47
Ratua-I	231.0	1453.0	335.64	0.50	167.82	125.87	62.94	37.76
Ratua-II	174.0	1453.0	252.82	0.50	126.41	94.81	47.41	28.45
Chanchal-I	162.0	1453.0	235.39	0.50	117.70	88.28	44.14	26.48
Chanchal-II	205.0	1453.0	297.87	0.50	148.94	111.71	55.86	33.52

Gazole	513.0	1453.0	745.39	0.50	372.70	279.53	139.77	83.86
Harishchandrapur-I	171.0	1453.0	248.46	0.50	124.23	93.17	46.59	27.95
Harishchandrapur-II	217.0	1453.0	315.30	0.50	157.65	118.24	59.12	35.47
				District Total	**2654.67**	**1991.05**	**995.58**	**597.33**

From **Table 8.4**, it is seen that at district level, total volume of surface runoff available in a year is 2654.67 MCM, out of which non-committed surface runoff available annually for rain water harvesting (after deducting the environmental flow) is 597.33 MCM. Thus only 22.5% of the available volume of surface runoff can be utilized for rain water harvesting. It is also revealed that a high variability exists in the volume of non-committed surface runoff at block level for implementing rain water harvesting. Highest water availability of 83.86 MCM is calculated for Gazole block and the lowest volume of 18.31 MCM is calculated for Kaliachak-I block. As discussed in Section 8.4, there is very little scope for implementing artificial recharge schemes in Malda district.

Based on Monsoon Rainfall of 1219.8 mm (year: 2019), total volume of water available for implementing rainwater harvesting for 27 Census Towns (Aiho, Kendua, Chanchal, Sahapur, Kachu Pukur, Rangavita, Bamangram, Jadupur, Baliadanga, Nazirpur, Chhatianmor, Alipur, Birodhi etc.) was estimated at 0.003 MCM, which would require an expenditure of Rupees Twelve Lakh for implementation of the scheme. For the two Municipal Bodies (English Bazar Municipality and Old Malda Municipality), the volume of rain water available for harvesting is estimated at 0.015 MCM with total expenditure of Rupees Forty Lakh for implementation of the scheme (Master Plan of Artificial Recharge, 2020).

8.7 Block Level Aquifer Management Plan, Malda district

For a detailed understanding of aquifer architecture, aquifer geometry and correlation between aquifers at block level, block wise Aquifer Management Plans (AMP) of Malda district are prepared. The AMPs also serve as an integral component for development of the Aquifer Information and Management System (AIMS), which is proposed to be launched through web based platform. The main objective of developing the AIMS is to facilitate the stakeholders in understanding the aquifer wise availability and chemical quality of groundwater for drinking, irrigational and industrial use. Aquifer Management Plans for 15 community developmental blocks in Malda district are given in the following pages.

Aquifer Management Plan **Kaliachak-I block, Malda district, West Bengal** **(112.0 km² area covered under NAQUIM)**	
GENERAL INFORMATION	
State Name	West Bengal
District name	Malda
Block Name	Kaliachak-I
Location	Located in the southern part of Malda district
Geographical Area	112.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Aquifer-I: Average depth range is from 20 to 45 m bgl (deep tube wells of state government are absent due to high Arsenic)
Major Aquifer System	Younger Alluvium (Aquifer Code - AL01):Single Aquifer System, depth range varies from 30-41 mbgl (based on limited Piezometer data of state government department)
Annual Rainfall	2019: 1139.4 mm, 2020: 1681.7 mm
AQUIFER DISPOSITION	
Aquifer Disposition	**Aquifer-I**: Phreatic aquifer occurring at shallow depth (<60 m) • Occurs throughout the block • Underlain by hard crystalline rocks (Precambrian basement of Garo-Rajmahal gap) at >100 m bgl (CGWB 2001) • Aquifer material is Younger Alluvium of Late Quaternary age • Generally, Aquifers occur in the depth range of 30.0 to 41.0 m bgl (CGWB, 2001)
Status of GW Exploration	Exploratory Wells: 0 Observation Wells: 0 Piezometers: 8 (State Water Investigation Directorate)
Aquifer Characteristics	Due to extremely high Arsenic concentration throughout Kaliachak-I block, no groundwater based water supply and distribution scheme has been implemented. As a consequence, litholog/strata chart of bore holes in this block are not available, thereby precluding characterization of Aquifers in this block.
Groundwater Monitoring Status	4 monitoring wells (at Kaliachak, Thakurbari, Sujapur and Khaschandpur/Makku Sahutala) Average DTW (pre-monsoon 2020): 3.46 m bgl Average DTW (post-monsoon 2020): 3.13 m bgl Average water table elevation ((pre-monsoon 2020): 26.54 m Average water table elevation ((post-monsoon 2020): 26.87 m
Groundwater Quality	➢ Aquifer – I (Single Aquifer System): Arsenic contamination reported in 317 habitations (Arsenic>0.01 mg/L). Total risk population = 392517 (Rural: 269058, Urban: 123459) ➢ NABL Data of CGWB, ER: During Special Drive on Arsenic (2015-16), Arsenic concentration in groundwater was found

to be varying randomly at various locations viz. Gidhnipara (0.009 mg/L), Nauda (0.035 mg/L), Jalalpur (0.057 mg/L), Chandpur (0.094 mg/L), Balidanga (0.164 mg/L), Kaliachak Dalal More (0.237 mg/L) and Sujapur (0.402 mg/L).

- Groundwater Monitoring Wells of CGWB: Arsenic concentration was variable e.g. Kaliachak (0.184 mg/L), Thakurbari (0.0767 mg/L) and Sujapur (0.001 mg/L). High magnesium (>30 mg/L) is recorded at Sujapur (43 mg/L), Kaliachak (44 mg/L) and Sultanganj (51 mg/L).

Aquifer Characteristics

AQUIFER	DEPTH RANGE (mbgl)	THICKNESS (m)	DISCHARGE (m^3/hr)	Drawdown (m)
Aquifer-I	30.0 – 41.0	14.3	180-200	2.0 – 4.0

*Transmissivity (T) and Storage Co-efficient(S) are not available

Groundwater Resource

*Total annual GW Recharge: 7537.06 ham
*Total Annual GW Extraction: 5040.65 ham
*Stage of GW Extraction: 66.88%
*Category: Safe

Future Water Demand

*Annual GW allocation for future domestic use (up to 2042): 511.56 ham

Aquifer Management plan

Groundwater Management Plan

Problem 1: Ground water contamination caused by arsenic in Younger Alluvium of Aquifer-I.

Block	Arsenic (<0.01 mg/L)		Arsenic (>0.01<0.05 mg/L)		Arsenic (>0.05 mg/L)		No. of tube wells with high Arsenic (maximum As concentration)
	%	Count	%	Count	%	Count	
Kaliachak-I	0	0	9.15	29	90.85	288	317 (0.216 mg/L)

Table showing details of tube wells with high Arsenic content

<u>Management strategy</u>:

1. Installation of arsenic removal plants to make potable water from the single aquifer system (Aquifer-I).
2. Rainwater harvesting.
3. Use of surface water in entire block, primarily due to Arsenic contamination in groundwater throughout this block (Arsenic Hot Spot area).
4. Alternate cropping (like horticulture instead of conventional paddy cultivation) to be adopted to eliminate bio-magnification of arsenic in food grains.
5. Implementation of modern irrigation practices like drip water irrigation system, sprinklers can be made.
6. Rain water harvesting and artificial recharge structures to be implemented.
7. For removal of Arsenic, water treatment plants have been established at Dariapur and Baishnab Nagar by the Public Health Engineering Directorate, Govt. of West Bengal by tapping surface water from Bhagirathi River.

AR & Conservation Possibilities	1. Schemes for Artificial Recharge techniques needs to be adopted in Kalaiachak-I block. 2. Recharge techniques should be adopted on priority in areas having post-monsoon depth to water level > 9 mbgl, and with long-term declining trend. 3. Total utilizable volume of surface runoff is 0.685 MCM. 4. Total area suitable for recharge is 2.04 km^2 whereas unsaturated aquifer volume for Artificial Recharge has been estimated at 12.248 MCM (CGWB 2020). 4. Using standard method (Dhruvanarayana, 1993), a total of 68.50 ham of rainwater has been calculated to be harvested. This water can be used for construction of suitable structures for artificial recharge and conservation of water. 5. Recharge structures recommended are: Percolation Tank (potential: 0.343 MCM), Re-excavation of Existing Tank with Recharge Shaft (0.137 MCM) and Injection Well (0.206 MCM) as per the Master Plan of Artificial Recharge (CGWB 2020).

Aquifer Management Plan **Kaliachak-II block, Malda district, West Bengal** **(223.0 km^2 area covered under NAQUIM)**	
GENERAL INFORMATION	
State Name	West Bengal
District name	Malda
Block Name	Kaliachak-II
Location	Located in the southern part of Malda district
Geographical Area	223.0 km^2
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Single aquifer system occurring at shallow (<60 m) to moderately deep (60 – 100 m) levels throughout the block (deep tube wells of state government are absent due to high Arsenic)
Major Aquifer System	Younger Alluvium (Aquifer Code - AL01): Single Aquifer System, depth range varies from is from 18-80 mbgl (based on limited Piezometer data of state government (SWID)
Annual Rainfall	2019: 1139.4 mm, 2020: 1681.7 mm
AQUIFER DISPOSITION	
Aquifer Disposition	**Aquifer-I**: Occurs under phreatic/semi confined condition • Promising aquifers at shallow to moderately deep levels • Occurs throughout the block • Underlain by hard crystalline rocks (Precambrian basement of Garo-Rajmahal gap) at >100 m bgl (CGWB 2001) • Aquifer material: Younger Alluvium (Holocene)
Status of GW Exploration	Exploratory Wells: 0 Observation Wells: 0 Piezometers: 6 (State Water Investigation Directorate)
Aquifer Characteristics	Due to extremely high Arsenic concentration throughout Kaliachak-II block, no groundwater based water supply and distribution scheme has been implemented. As a consequence, litholog/strata chart of bore holes in this block are not available, thereby precluding characterization of Aquifers in this block.
Groundwater Monitoring Status	3 monitoring wells (at Kuriatar, Mothabari and Puratan Pataldanga) Average DTW (pre-monsoon 2020): 2.91 m bgl Average DTW (post-monsoon 2020): 2.76 m bgl Average Water Table elevation (pre-monsoon 2020): 26.54 m Average Water Table elevation (post-monsoon 2020): 26.87 m
Groundwater Quality	➢ Aquifer – I: Arsenic contamination reported in 317 habitations (Arsenic>0.01 mg/L). Total risk population = 392517 (Rural: 269058, Urban: 123459) ➢ NABL Data of CGWB, ER: During Special Drive on Arsenic (2015-16), Arsenic concentration in groundwater was found

<table>
<tr><td></td><td>to be varying randomly at various locations viz. at Meherapur/Birpara (0.001 mg/L), Ganga Prasad Colony (0.002 mg/L), Kashim Bazar (0.014 mg/L), Puratan Pataldanga (0.030 mg/L), Birampur (0.035 mg/L), Kahala (0.036 mg/L), Durlavpur/Kakmari (0.054 mg/L) and Raipara (0.078 mg/L).
➢ Groundwater Monitoring Wells of CGWB: Arsenic concentration was variable and high e.g. at Kuriatar (0.026 mg/L) and Mothabari (0.034 mg/L and 0.049 mg/L).). High magnesium (>30 mg/L) is recorded at Puratan Pataldanga (52 mg/L).</td></tr>
<tr><td>Aquifer Characteristics</td><td><table>
<tr><td>AQUIFER</td><td>DEPTH RANGE (mbgl)</td><td>THICKNESS (m)</td><td>DISCHARGE (m^3/hr)</td><td>DRAW DOWN (m)</td></tr>
<tr><td>Aquifer-I</td><td>18.0-80.0</td><td>--</td><td>210-215</td><td>3.5-6.0</td></tr>
</table>*Transmissivity (T) and Storage Co-efficient(S) are not available</td></tr>
<tr><td>Groundwater Resource</td><td>*Total Annual GW Recharge: 13691.00 ham
*Total Annual GW Extraction: 3925.64 ham
*Stage of GW Extraction: 28.67%
*Category: Safe</td></tr>
<tr><td>Future Water Demand</td><td>*Annual GW allocation for future domestic use (up to 2042): 274.26 ham</td></tr>
<tr><td colspan="2">Aquifer Management plan</td></tr>
<tr><td>AR & Water Conservation Possibilities</td><td>1. Artificial Recharge in Kaliachak-II block is generally not suitable for implementing Artificial Recharge schemes according to the latest Master Plan for Artificial Recharge (CGWB 2020).
2. However, water conservation through open area rainwater harvesting in rural areas may be adopted depending on detailed village level (need based) survey.</td></tr>
</table>

Aquifer Management Plan **Kaliachak-III block, Malda district, West Bengal** **(260.0 km² area covered under NAQUIM)**	
GENERAL INFORMATION	
State Name	West Bengal
District name	Malda
Block Name	Kaliachak-III
Location	Located in the southernmost part of Malda district
Geographical Area	260.0 km^2
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Single Aquifer System occurring at shallow (<60 m) level (deep tube wells of state government are absent due to high Arsenic)
Major Aquifer System	Younger Alluvium(Aquifer Code - AL01):Average depth range variable for Aquifer-1A and Aquifer-1B Aquifer-1A: 38.0 – 42.0 m bgl Aquiufer-1B: 55.0 – 78.0 m bgl (based on limited Piezometer data of state government department)
Annual Rainfall	2019: 1335.0 mm, 2020: 1643.3 mm
AQUIFER DISPOSITION	
Aquifer Disposition	**Aquifer-I**: Phreatic aquifer (shallow to moderately deep aquifers without thick (>10 m) clay layers) • Occurs throughout the block • Underlain by hard crystalline rocks (Precambrian basement of Garo-Rajmahal gap) at >100 m bgl (CGWB 2001) • Aquifer material: Younger Alluvium (Holocene)
Status of GW Exploration	Exploratory Wells: 0 Observation Wells: 0 Piezometers: 2 (State Water Investigation Directorate/SWID)
Aquifer Characteristics	Due to extremely high Arsenic concentration throughout Kaliachak-II block, no groundwater based water supply and distribution scheme has been implemented. As a consequence, litholog/strata chart of bore holes in this block are not available, thereby precluding characterization of Aquifers in this block.
Groundwater Monitoring Status	6 monitoring wells Average DTW (pre-monsoon 2020): 2.21 m bgl Average DTW (post-monsoon 2020): 1.85 m bgl Average Water Table elevation (pre-monsoon 2020): 21.12 m Average Water Table elevation (post-monsoon 2020): 20.82 m
Groundwater Quality	➢ Aquifer – I: Arsenic contamination reported in 145 habitations (Arsenic > 0.01 mg/L). Total risk population = 359071 (Rural: 329147, Urban: 29924) ➢ NABL Data of CGWB, ER: During Special Drive on Arsenic (2015-16), Arsenic concentration in groundwater was found to be varying randomly at various locations viz. at Satangapar (0.001 mg/L), Baishnab Nagar (0.003 mg/L), Kalinagar (0.005 mg/L), Krishnapur (0.025 mg/L) and 18 Mile/Jalalditola (0.115 mg/L).

- ➢ Groundwater Monitoring Wells of CGWB: Arsenic concentration was found to be varying e.g. 0.004 mg/L (Mahajantala), 0.008 mg/L (Doriapur), 0.022 (17 Mile), 0.044 (16 mile), 0.060 mg/L (Birnagar) and 0.129 mg/L (Pagla Bridge). High magnesium (>30 mg/L) is recorded at Birnagar (77 mg/L).

Aquifer Potential

AQUIFER	DEPTH RANGE (mbgl)	THICKNESS (m)	DISCHARGE (m^3/hr)	DRAW DOWN (m)
Aquifer-IA	38.0-42.0	4.0	--	--
Aquifer-IB	55.0-78.0	23.0	202-215	3.0-6.0

Groundwater Resource

*Annual Extractable GW Recharge: 20561.12 ham
*Total Annual GW Extraction: 12602.06 ham
*Stage of GW Extraction: 61.29%
*Category: Safe

Future Water Demand

*Annual GW allocation for future domestic use (up to 2042): 473.31 ham

Aquifer Management Plan

Groundwater Management Plan

Problem 1: Ground water contamination caused by arsenic in Younger Alluvium of Aquifer-I (single aquifer system).

Block	**Arsenic (<0.01 mg/L)**		**Arsenic (>0.01<0.05 mg/L)**		**Arsenic (>0.05 mg/L)**		**No. of tube wells with high Arsenic (maximum As concentration)**
	%	**Count**	**%**	**Count**	**%**	**Count**	
Kaliachak-III	0	0	19.31	28	80.69	117	145 (0.992 mg/L)

Table showing percentage of tube wells having arsenic content.

Management strategy:

1. Installation of arsenic removal plants to make potable water from Aquifer-I.
2. Rainwater harvesting, especially open area rainwater harvesting in the rural areas.
3. Conjunctive use of surface water and ground water.
4. Alternate cropping (like horticulture instead of conventional paddy cultivation) to be adopted to eliminate bio-magnification of arsenic in food grains.
5. Implementation of modern irrigation practices like drip water irrigation system, sprinkler based micro irrigation system can be done.

AR & Water Conservation Possibilities

1. Artificial Recharge in Kaliachak-III block is generally not suitable for implementing Artificial Recharge schemes according to the latest Master Plan for Artificial Recharge (CGWB 2020).

2. However, water conservation through open area rainwater harvesting in rural areas may be adopted depending on detailed village level (need based) survey.

Aquifer Management Plan

English Bazar block, Maldadistrict, West Bengal

(242.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	English Bazar
Location	Located in south eastern part of Malda district
Geographical Area	242.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Aquifer Code: AL) Single Aquifer System
Major Aquifer System	Younger Alluvium of Holocene age (Code- AL01) Aquifer-IA:Depth range varies from 25.0 to 46.0 mbgl (shallow aquifer) Aquifer-1B: Depth range varies from 52.0 to 110.0 mbgl (moderately deep aquifer)
Annual Rainfall	2019: 1484.5 mm, 2020: 1738.0 mm

AQUIFER DISPOSITION

Aquifer Disposition

Aquifer-I: Phreatic aquifer (shallow to moderately deep)

- Occurs throughout the block
- Underlain by hard crystalline rocks (Garo-Rajmahal Gap)
- Aquifer material is Younger Alluvium (Holocene age)

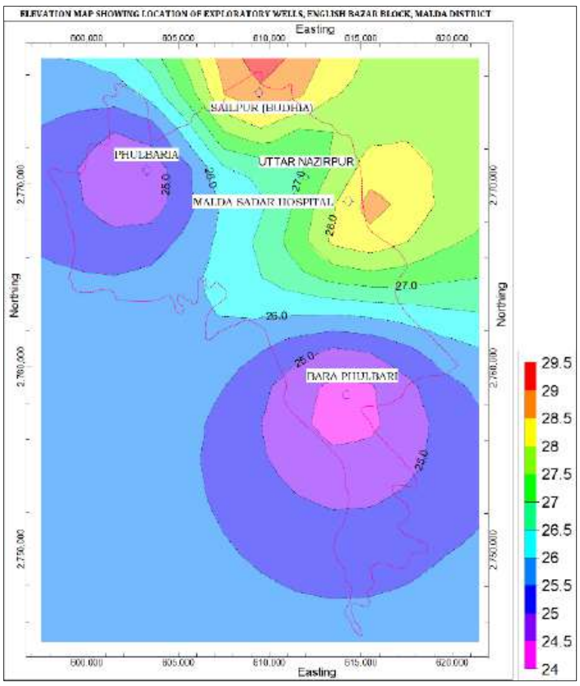


Fig. 1: Elevation map showing location of Exploratory Wells, English Bazar block

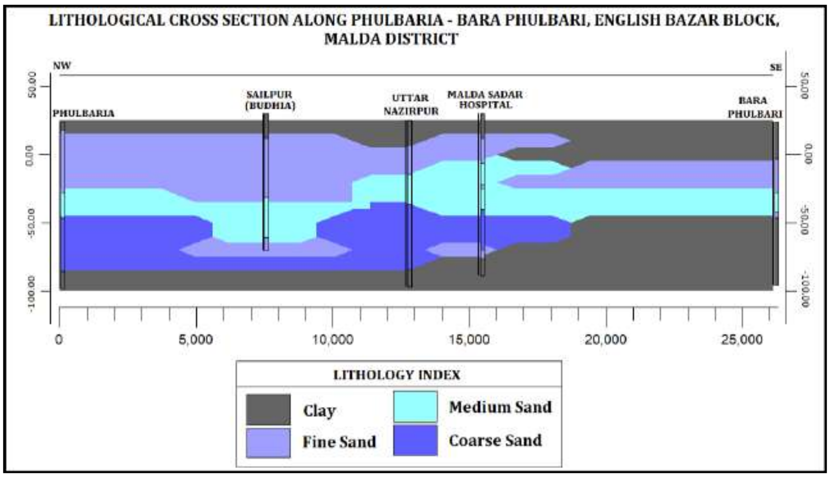


Fig. 2: Lithological cross section along NW-SE, English Bazar block

Status of GW Exploration	Exploratory Wells: 4 Observation Wells:0 Piezometers: 5 (State Water Investigation Directorate)
Aquifer Characteristics	

AQUIFER	DEPTH RANGE (mbgl)	THICKNESS (m)	DISCHARGE (m^3/hr)	T (m^2/day)
Aquifer-IA	25.0-46.0	21.0	0.6-40.0	207.81
Aquifer-IB	52.0-110.0	58.0		

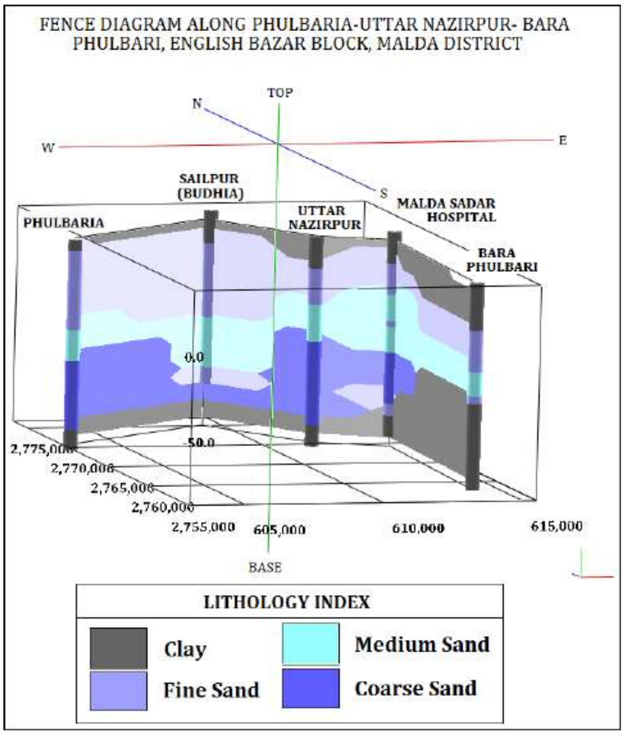
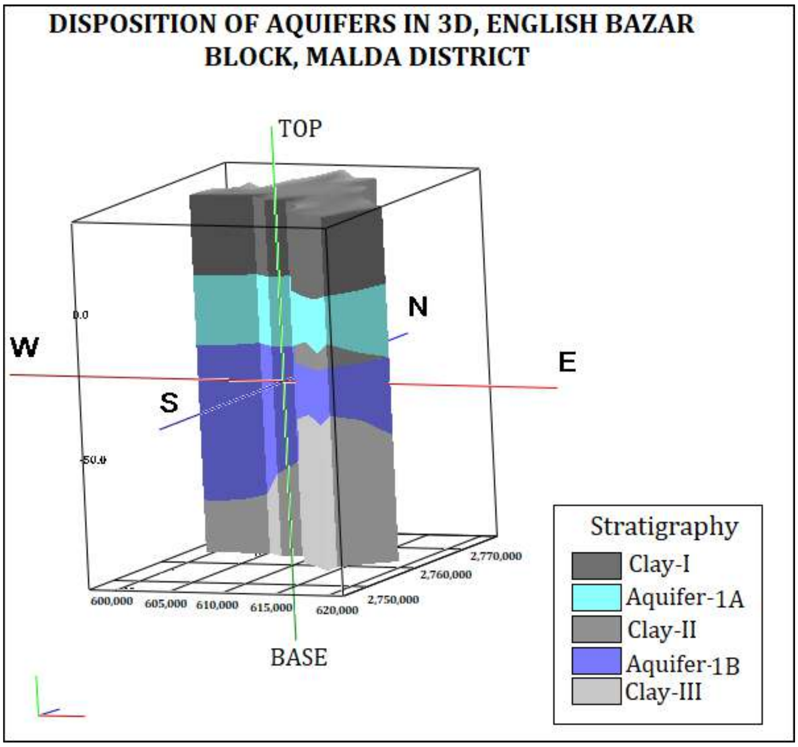


Fig. 3: Fence Diagram showing correlation of aquifers, English Bazar block

	 **Fig. 4: Block Diagram showing aquifer disposition in 3-D, English Bazar block**
Groundwater Monitoring Status	5 monitoring wells (Bholanathpur, Bot Tolly, Milki, Krishna Nagar, Chhoto Mohanpara) Average DTW (pre-monsoon 2020): 3.81 m bgl Average DTW (post-monsoon 2020): 2.27 m bgl Average water table elevation ((pre-monsoon 2020): 21.19 m Average water table elevation ((post-monsoon 2020): 22.73 m
Groundwater Quality	*Aquifer–I: Arsenic contamination reported in 155 habitations (Arsenic >0.01 mg/L). Total risk population = 274627 (Rural: 242797, Urban: 31830) * NABL Data of CGWB, ER: Arsenic concentration in groundwater found to be varying from 0.001 mg/L at Bholanathpur & Chhoto Mohanpara, 0.028 mg/L at Phulbaria and 0.15 mg/L at Milki (CGWB Special Drive on Arsenic, 2016 and NAQUIM studies: 2020-21)
Groundwater Resource (as on 31-3-2017)	*Annual Extractable GW Recharge: 16007.84 ham *Total Annual GW Extraction: 6900.32 ham *Stage of GW Extraction: 43.11% *Category: Safe
Future Water Demand (as on 31-3-2017)	*GW allocation for future domestic use (up to 2042 AD): 662.85 ham
Aquifer Management plan	
Groundwater Management Plan	**Problem 1**: Ground water contamination caused by arsenic in Younger Alluvium of Aquifer-I.

<table>
<tr>
<td></td>
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<table>
<tr><th rowspan="2">Block</th><th colspan="2">Arsenic (<0.01 mg/L)</th><th colspan="2">Arsenic (>0.01<0.05 mg/L)</th><th colspan="2">Arsenic (>0.05 mg/L)</th><th rowspan="2">No. of Tube Wells with high Arsenic (maximum As concentration)</th></tr>
<tr><th>%</th><th>Count</th><th>%</th><th>Count</th><th>%</th><th>Count</th></tr>
<tr><td>English Bazar</td><td>0</td><td>0</td><td>34.19</td><td>53</td><td>65.81</td><td>102</td><td>155 (0.238 mg/L at Kanaipur)</td></tr>
</table>
<u>Groundwater management strategies</u>:

Installation of arsenic removal plants to extract potable water from Aquifer-I.
Rainwater harvesting in rural areas.
Conjunctive use of surface water and ground water.
Alternate cropping (like horticulture instead of conventional paddy cultivation) to be adopted to eliminate bio-magnification of arsenic in food grains.
Implementation of modern irrigation practices like drip water irrigation system, sprinklers can be made.

</td>
</tr>
<tr>
<td>Artificial Recharge and Water Conservation Possibilities</td>
<td>
1. Implementation of Artificial Recharge schemes in English Bazar block is generally not feasible according to the latest Master Plan for Artificial Recharge (CGWB 2020).
2. However, water conservation through open area rainwater harvesting in rural areas may be adopted depending on detailed village level (need based) survey.
</td>
</tr>
</table>

Aquifer Management Plan

Manikchak block, Malda district, West Bengal

(325.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Manikchak
Location	Located in the western part of Malda district
Geographical Area	325.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Single Aquifer System occurring at shallow (<60 m) level
Major Aquifer System	Younger Alluvium(Aquifer Code - AL01):Average depth range variable for Aquifer-1A and Aquifer-1B Aquifer-1A: – 12.2 -70.1 m bgl Aquiufer-1B: 73.2 – 103.6 m bgl
Annual Rainfall	2019: 1461.0 mm, 2020: 1550.2 mm

AQUIFER DISPOSITION

Aquifer Disposition

Aquifer-I: Phreatic aquifer (shallow to moderately deep aquifers without thick (>10 m) clay layers)

- Occurs throughout the block
- Underlain by hard crystalline rocks (Precambrian basement of Garo-Rajmahal gap)
- Aquifer material: Younger Alluvium (Holocene)

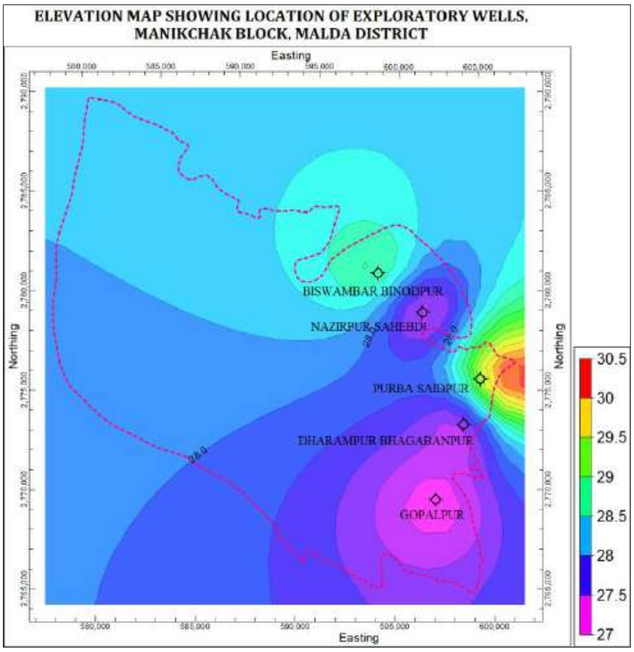

Fig. 1. Elevation map showing location of Exploratory Wells, Manikchak block

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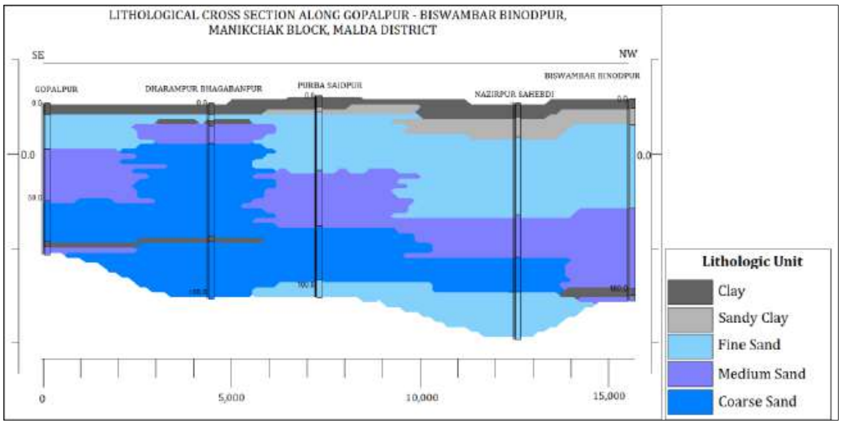

Fig 2: Lithological cross section along SE-NW, Manikchak block

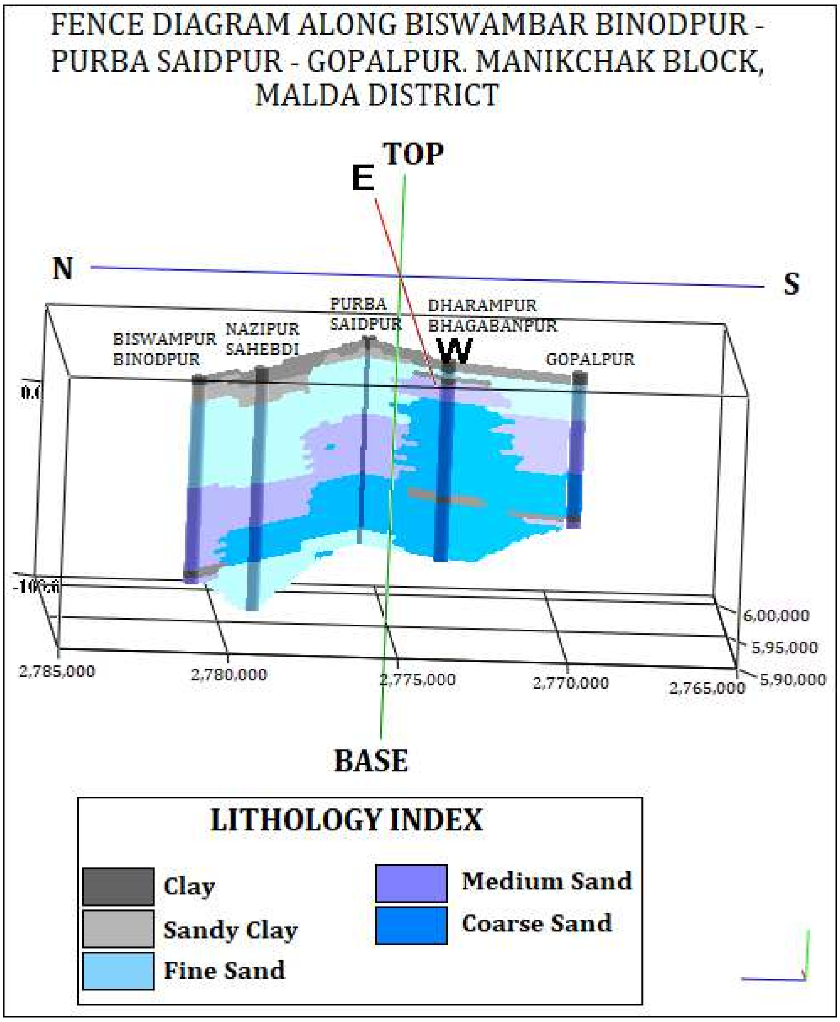

Fig. 3. Fence diagram showing disposition of Aquifers along Biswambar Binodpur-Gopalpur Section, Manikchak block

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</tr>
<tr>
<td>Status of GW Exploration</td>
<td>Exploratory Wells: 5
Observation Wells: 0
Piezometers: 3 (State Water Investigation Directorate/SWID)</td>
</tr>
</table>

<table>
<tr>
<td>Aquifer Characteristics</td>
<td>
<table>
<tr><th>AQUIFER</th><th>DEPTH RANGE (mbgl)</th><th>THICKNESS (m)</th><th>DISCHARGE (m^3/hr)</th><th>DRAW DOWN (m)</th></tr>
<tr><td>Aquifer-IA</td><td>12.2-70.1</td><td>57.9</td><td rowspan="2">207.00</td><td rowspan="2">3.0</td></tr>
<tr><td>Aquifer-IB</td><td>73.2-103.6</td><td>30.4</td></tr>
</table>

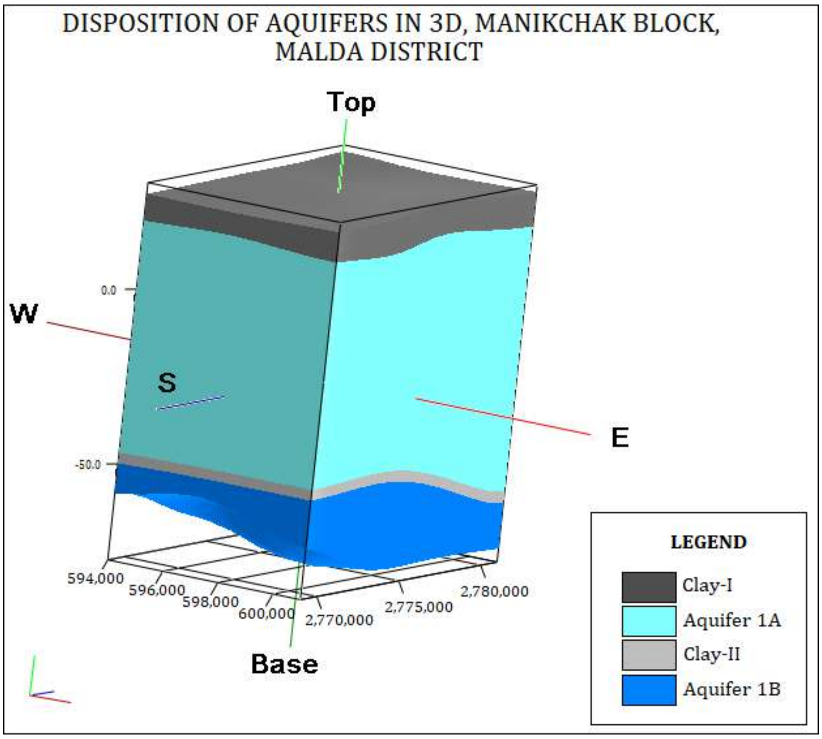

Fig. 4. Block Diagram showing Aquifer disposition in 3-D, Manikchak block
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<tr>
<td>Groundwater Monitoring Status</td>
<td>
3 monitoring wells
Average DTW (pre-monsoon 2020): 5.19 m bgl
Average DTW (post-monsoon 2020): 2.76 m bgl
Average Water Table elevation (pre-monsoon 2020): 15.41 m
Average Water Table elevation (post-monsoon 2020): 18.39 m
</td>
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<tr>
<td>Groundwater Quality</td>
<td>
➢ Aquifer–I: Arsenic contamination reported in 107 habitations (Arsenic>0.01 mg/L). Total risk population = 269813 (Rural: 269813, Urban: 0)
➢ NABL Data of CGWB, ER: Arsenic concentration varying from 0.0003 mg/L at Nazirpur to 0.215 mg/L at Mohana. High Arsenic was also reported from Damodarpur (0.131 mg/L) and from Manikchak (0.112 mg/L).
➢ Data of PHED, Govt. of West Bengal: High arsenic concentration (0.0.051 and 0.053 mg/L) were reported from two tube wells of Uttar Chandipue Water Supply Scheme. Very high Iron (2.90 and 3.35 mg/L) were also recorded from these tube wells (August 2019).
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Groundwater Resource	*Annual Extractable GW Recharge: 18626.75 ham *Total Annual GW Extraction: 4778.78 ham *Stage of GW Extraction: 25.66% *Category: Safe
Future Water Demand	*Annual GW allocation for future domestic use (up to 2042): 356.53 ham

Aquifer Management plan

Groundwater Management Issues	
Groundwater Management Plan	**Problem 1**: Ground water contamination caused by arsenic in younger Alluvium of Aquifer-I (single aquifer system).

Block	Arsenic (<0.01 mg/L)		Arsenic (>0.01<0.05 mg/L)		Arsenic (>0.05 mg/L)		No. of Tube Wells with high Arsenic (maximum As concentration)
	%	Count	%	Count	%	Count	
Manikchak	0	0	18.69	20	81.31	87	107 (0.072 mg/L)

Table showing percentage of tube wells having arsenic content.

<u>Groundwater management strategies</u>:

1. Installation of arsenic removal plants to make potable water from Aquifer-I.
2. Rainwater harvesting in rural areas.
3. Use of surface water.
4. Alternate cropping (like horticulture instead of conventional paddy cultivation) to be adopted to eliminate bio-magnification of arsenic in food grains.
5. Alternate cropping (like horticulture instead of conventional paddy cultivation) to be adopted to eliminate bio-magnification of arsenic in food grains.
6. Implementation of modern irrigation practices like drip water irrigation system, sprinklers can be made.

AR & Conservation Possibilities	1. Artificial Recharge schemes in Manikchak block are generally not suitable according to the latest Master Plan for Artificial Recharge (CGWB 2020). 2. However, water conservation through open area rainwater harvesting in rural areas may be adopted depending on detailed village level (micro level) survey.

Aquifer Management Plan
Ratua-I block, Malda district, West Bengal
(231.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Ratua-I
Location	Located in the western part of Malda district
Geographical Area	231.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Single Aquifer System occurring at shallow depth (<60 m bgl)
Major Aquifer System	Younger Alluvium(Aquifer Code-AL01): Average depth range variable for Aquifer-1A and Aquifer-1B Aquifer-1A: 38.50 – 42.20 m bgl Aquiufer-1B: 53.0 – 57.0 m bgl
Annual Rainfall	2019: 1461.0mm, 2020: 1550.2 mm

AQUIFER DISPOSITION

Aquifer Disposition	**Aquifer-I**: Phreatic aquifer (shallow to moderately deep aquifers without thick (>10 m) clay layers) • Occurs throughout the block • Underlain by hard crystalline rocks (Precambrian basement of Garo-Rajmahal gap) • Aquifer material: Younger Alluvium (Holocene)

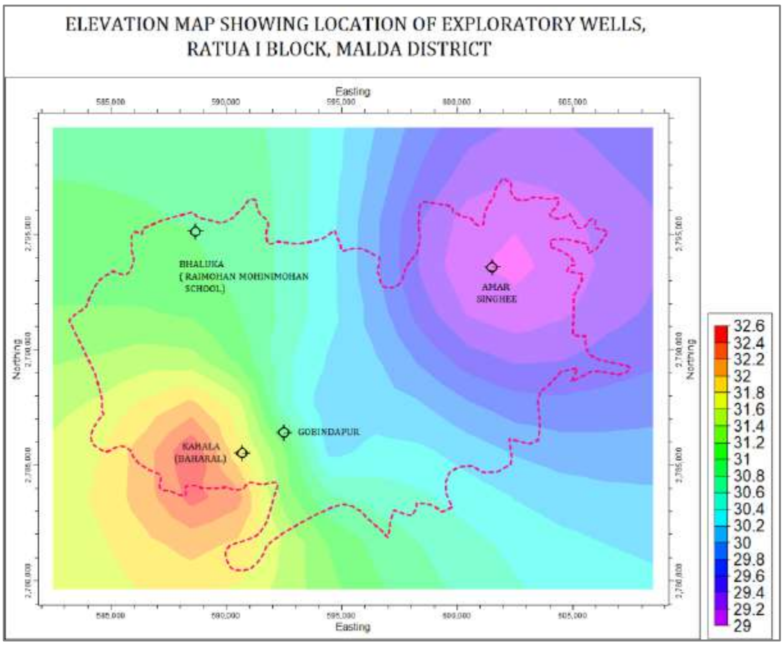


Fig. 1: Elevation map showing location of Exploratory Wells, Ratua-I block

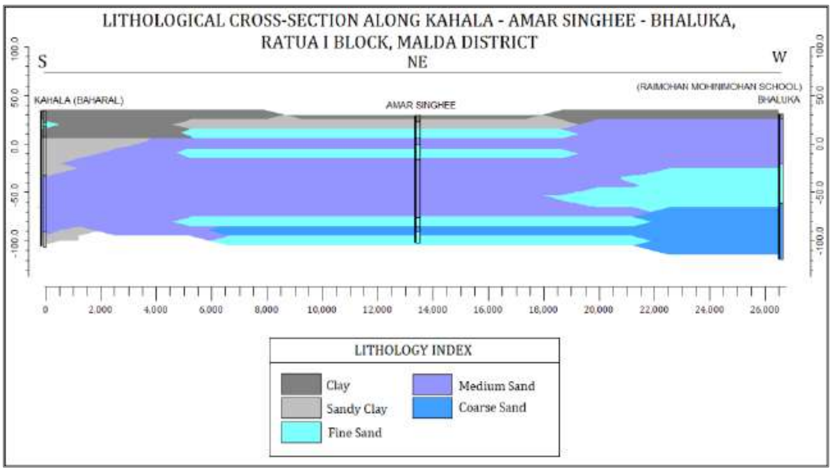


Fig. 2: Lithological cross section along South-North East-West, Ratua-I block

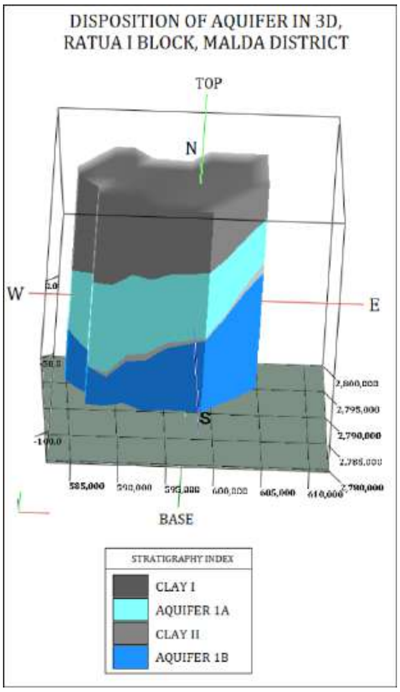


Fig. 3. Block Diagram showing disposition of aquifers in 3-D, Ratua-I block

Status of GW Exploration

Exploratory Wells: 3
Observation Wells: 0
Piezometers: 3 (State Water Investigation Directorate/SWID)

Aquifer Characteristics

AQUIFER	DEPTH RANGE (mbgl)	THICKNESS (m)	DISCHARGE (m^3/hr)	DRAW DOWN (m)
Aquifer-IA	24.0-55.5	31.5	167.5 - 205.0	2.5-5.44
Aquifer-IB	61.5-131.2	69.7		

Groundwater Monitoring Status

3 monitoring wells
Average DTW (pre-monsoon 2020): 5.19 m bgl
Average DTW (post-monsoon 2020): 2.76 m bgl
Average Water Table elevation (pre-monsoon 2020): 15.41 m

	Average Water Table elevation (post-monsoon 2020): 18.39 m
Groundwater Quality	➢ Aquifer–I: Arsenic contamination reported in 234 habitations (Arsenic>0.01 mg/L). Total risk population = 275388 (Rural: 275388, Urban: 0) ➢ NABL Data of CGWB, ER: During Special Drive on Arsenic (2016), arsenic concentration in groundwater was found to be variable viz. 0.00004 mg/L at Motiganj, 0.001 mg/L at Pakurtala, 0.006 mg/L at Durgapur, 0.019 mg/L at Makaiya and 0.138 mg/L at Baharal. ➢ NAQUIM Studies (2019-2021): Arsenic concentration was found to be variable viz. 0.001 mg/L at Ratanapur Hat (Samshi) and 0.007 mg/L at Debipur. High magnesium (>30 mg/L) was found at Ratua (36 mg/L) & Ratanpur Hat (52 mg/L) during pre-monsoon, 2020.
Aquifer Potential	Aquifers in Ratua-I block have good groundwater potential, ranging from 53 litre per second (lps) to 57 lps. Transmissivity (Shallow Exploratory Well of CGWB) was found to be varying from 1140.74 m^2/day to 1824.30 m^2/day.
Groundwater Resource (as on 31-3-2017)	*Annual Extractable GW Recharge: 15068.04 ham *Total Annual GW Extraction: 10106.33 ham *Stage of GW Extraction: 67.07 % *Category: Safe
Future Water Demand (as on 31-3-2017)	*Annual GW allocation for future domestic use (up to 2042 AD): 371.04 ham

Aquifer Management plan

Groundwater Management Plan

Problem 1: Ground water contamination caused by arsenic in Younger Alluvium of Aquifer-I (single aquifer system).

Block	**Arsenic (<0.01 mg/L)**		**Arsenic (>0.01<0.05 mg/L)**		**Arsenic (>0.05 mg/L)**		**No. of Tube Wells with high Arsenic (maximum As concentration)**
	%	**Count**	**%**	**Count**	**%**	**Count**	
Ratua-I	0	0	40.60	95	59.40	139	234 (0.05 mg/L at Darbasini)

Table showing percentage of tube wells having arsenic content, Ratua-I block.

<u>Management strategy</u>:

1. Installation of arsenic removal plants to make potable water from Aquifer-I.
2. Rainwater harvestingin rural areas need to be implemented.
3. Conjunctive use of surface water and ground water.
4. Alternate cropping (like horticulture instead of conventional paddy cultivation) to be adopted to eliminate bio-magnification of arsenic in food grains.
5. Implementation of modern irrigation practices like drip irrigation system, sprinkler based micro irrigation system can be done.
6. Crops suggested for better management are wheat, pulses, mustard, vegetables, which require low water column depth and thus have low crop water requirement.

Artificial Recharge and Water Conservation Possibilities	1. The areas in Ratua-I block are generally not suitable for implementing Artificial Recharge schemes according to the latest Master Plan for Artificial Recharge (CGWB 2020). 2. However, water conservation through open area rainwater harvesting in rural areas and roof top rainwater harvesting in semi-urban areas should be adopted depending on local hydrometeorological conditions.

Aquifer Management Plan
Ratua-II block, Malda district, West Bengal
(174.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Ratua-II
Location	Located in the central part of Malda district
Geographical Area	174.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Single Aquifer System occurring at shallow (<60 m) to intermediate (>60 but <120 m) depth
Major Aquifer System	Younger Alluvium (Aquifer Code- AL01): Average depth range variable for Aquifer-1A and Aquifer-1B Aquifer-1A: 43.8– 57.0 m bgl Aquiufer-1B: 91.0 – 109.0 m bgl
Annual Rainfall	2019: 1461.0 mm, 2020: 1550.2 mm

AQUIFER DISPOSITION

Aquifer Disposition	**Aquifer-I**: Confined aquifers (shallow to moderately deep aquifers with thick (>10 m) clay layers) • Occurs throughout the block • Underlain by hard crystalline rocks (basalt? with conchoidal fractures) at >145 m, as seen at Araidanga • Aquifer material: Younger Alluvium (Holocene)

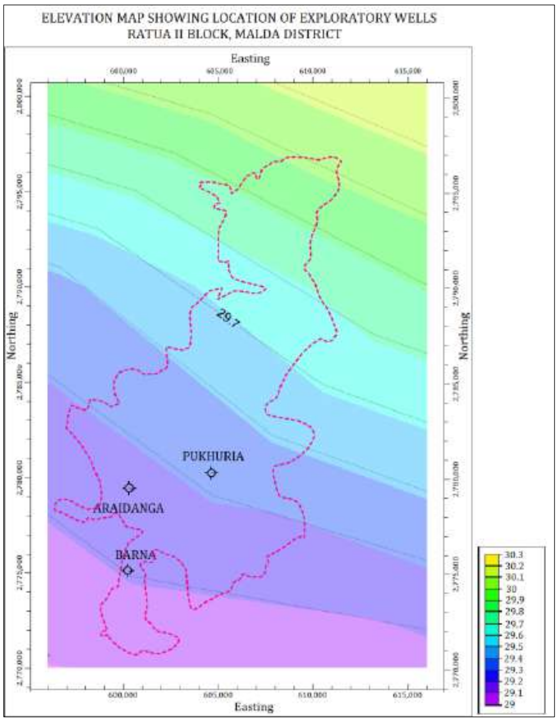


Fig. 1: Elevation map showing location of Exploratory Wells, Ratua-II block

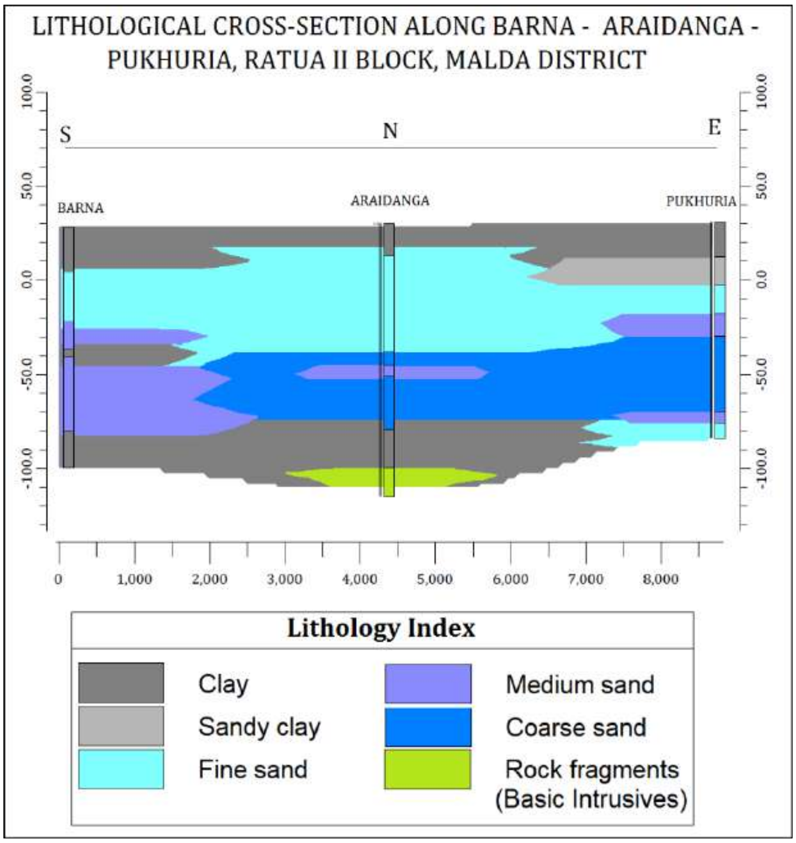


Fig. 2: Lithological cross section along South-North, Ratua-II block

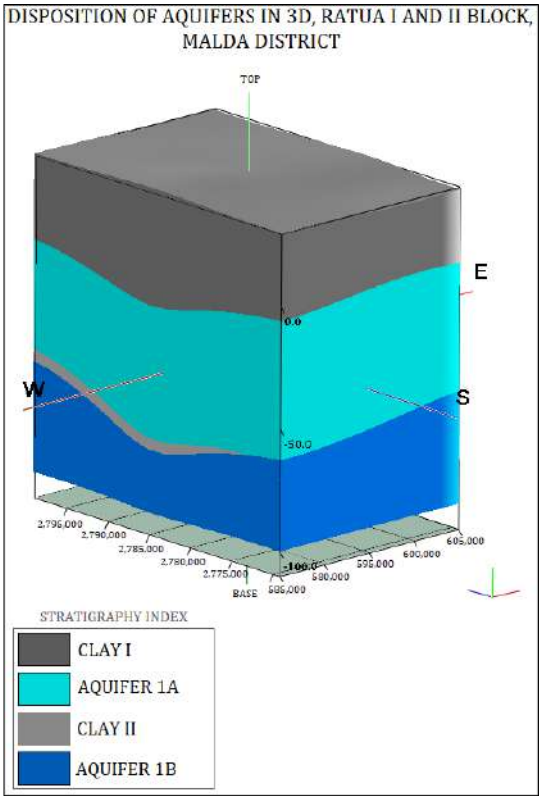


Fig. 3: Block Diagram showing aquifer disposition in 3-D, Ratua-II block

<table>
<tr><td></td><td></td></tr>
<tr><td>Status of GW Exploration</td><td>Exploratory Wells: 3
Observation Wells: 1 (CGWB)
Piezometers: 3 (State Water Investigation Directorate/SWID)</td></tr>
<tr><td>Aquifer Characteristics</td><td>
<table>
<tr><th>AQUIFER</th><th>DEPTH RANGE (mbgl)</th><th>THICKNESS (m)</th><th>DISCHARGE (m^3/hr)</th><th>DRAW DOWN (m)</th></tr>
<tr><td>Aquifer-IA</td><td>17.2-109.4</td><td>13.2</td><td rowspan="2">42.0 – 200.0</td><td rowspan="2">0.99 – 1.39</td></tr>
<tr><td>Aquifer-IB</td><td>129.8 – 140.0</td><td>18.0</td></tr>
</table>
</td></tr>
<tr><td>Groundwater Monitoring Status</td><td>3 monitoring wells
Average DTW (pre-monsoon 2020): 5.27 m bgl
Average DTW (post-monsoon 2020): 4.68m bgl
Average Water Table elevation (pre-monsoon 2020): 14.76 m
Average Water Table elevation (post-monsoon 2020): 15.32 m</td></tr>
<tr><td>Groundwater Quality</td><td>➢ Aquifer–I: Arsenic contamination reported in 78 habitations (Arsenic >0.01 mg/L). Latest data shows Arsenic concentration varying from 0.003 mg/L at Nasipur Water Supply Scheme to 0.016 mg/L at Araidanga Water Supply Scheme (PHED 2020). Total risk population affected by Arsenic contamination in Ratua-II block is 202080 (Rural: 202080, Urban: 0)
➢ NABL Data of CGWB, ER: During Special Drive on Arsenic (Period: 2015-16), high Arsenic was found at Naugama (0.003 mg/L), Araidanga (0.019 mg/L), Paranpur (0.035 mg/L & 0.065 mg/L). During groundwater exploration at Araidanga (2009) Arsenic concentration varied from 0.033 to 0.045 mg/L.</td></tr>
<tr><td>Aquifer Potential</td><td>Aquifers in Ratua-II block have good groundwater potential. Data of CGWB indicates that sustainable discharge was variable from 50 litre per second (lps) to 56 lps.</td></tr>
<tr><td>Groundwater Resource (as on 31-3-2017)</td><td>*Annual Extractable GW Recharge: 15670.95 ham
*Total Annual GW Extraction: 10436.25 ham
*Stage of GW Extraction: 66.60%
*Category: Safe</td></tr>
<tr><td>Future Water Demand (as on 31-3-2017)</td><td>*Annual GW allocation for future domestic use (up to 2042): 281.35 ham</td></tr>
<tr><td colspan="2">Aquifer Management plan</td></tr>
<tr><td>Groundwater Management Plan</td><td>Problem 1: Ground water contamination caused by arsenic in younger Alluvium of Aquifer-I (single aquifer system).
<table>
<tr><th rowspan="2">Block</th><th colspan="2">Arsenic (<0.01 mg/L)</th><th colspan="2">Arsenic (>0.01<0.05 mg/L)</th><th colspan="2">Arsenic (>0.05 mg/L)</th><th rowspan="2">No. of Tube Wells with high Arsenic (maximum As concentration)</th></tr>
<tr><th>%</th><th>Count</th><th>%</th><th>Count</th><th>%</th><th>Count</th></tr>
<tr><td>Ratua-II</td><td>0</td><td>0</td><td>55.13</td><td>43</td><td>44.87</td><td>35</td><td>78
(0.065 mg/L at Paranpur)</td></tr>
</table>
</td></tr>
</table>

	Table showing percentage of wells having high arsenic content. **Problem 2**: Ground water contamination caused by fluoride in younger Alluvium of Aquifer-I (single aquifer system). High fluoride concentration was reported in tube wells in Ratua-II block. NABL data of CGWB, ER shows fluoride concentration above the maximum permissible limit at Sripur (4.54 mg/L) and Pirganj (1.50 mg/L) during NAQUIM studies (period: 2019-20). **Management strategy:** 1. Installation of arsenic removal plants to make potable water from Aquifer-I. 2. Rainwater harvesting, especially open area rainwater harvesting in the rural areas of Ratua-II block. 3. Conjunctive use of surface water and ground water. 4. Alternate cropping (like horticulture instead of conventional paddy cultivation) to be adopted to eliminate bio-magnification of arsenic in food grains. 5. In areas affected with high fluoride concentration in groundwater, surface water-based water treatment plants need to be established by the state government.
Artificial Recharge and Water Conservation Possibilities	1. The areas in Ratua-II block are generally not suitable for implementing Artificial Recharge schemes according to the latest Master Plan for Artificial Recharge (CGWB 2020). 2. However, water conservation through open area rainwater harvesting in rural areas may be adopted depending on local hydrometeorological conditions.

Aquifer Management Plan
Chanchal-I block, Malda district, West Bengal

(162.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Chanchal-I
Location	Located in the northern part of Malda district
Geographical Area	162.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Two Aquifer System, first aquifer occurring at shallow to intermediate (>60<100 m) depth and second (deeper) aquifer occurring at >100 m depth
Major Aquifer System	Younger Alluvium (Aquifer Code - AL01): Average depth range variable for Aquifer-1A and Aquifer-1B Aquifer-I: 21.0 – 100.0 m bgl Aquifer-II: 124.0 – 165.0 m bgl
Annual Rainfall	2019: 1461.0 mm, 2020: 1550.2 mm

AQUIFER DISPOSITION

Aquifer Disposition	**Aquifer-I**: Confined aquifers (shallow to moderately deep aquifers with thick (>10 m) clay layers) • Occurs throughout the block • Aquifer material: Younger Alluvium (Holocene) **Aquifer-II:** Confined aquifers at deeper levels (>100 m bgl and extending to >150 m bgl) • Occurs throughout the block

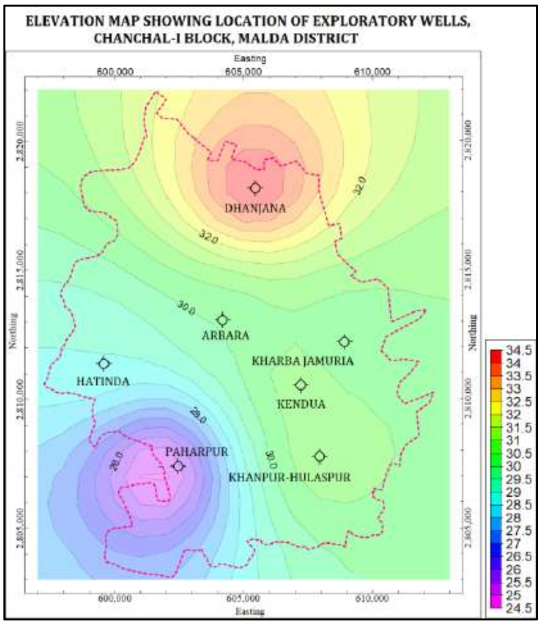


Fig. 1: Elevation map showing location of Exploratory Wells, Chanchal-I block

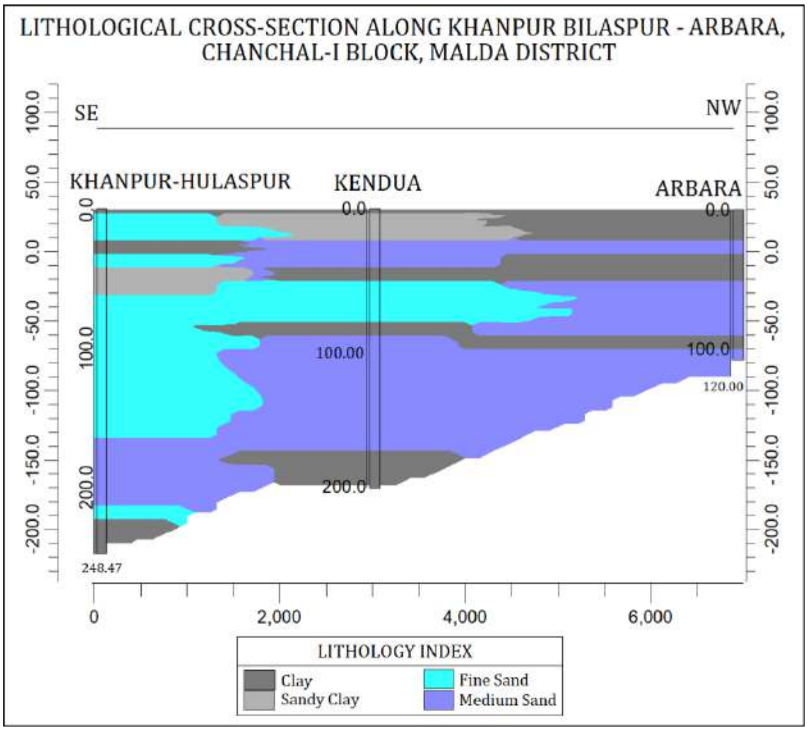


Fig. 2. Lithological cross section along SE-NW, Chanchal-I block

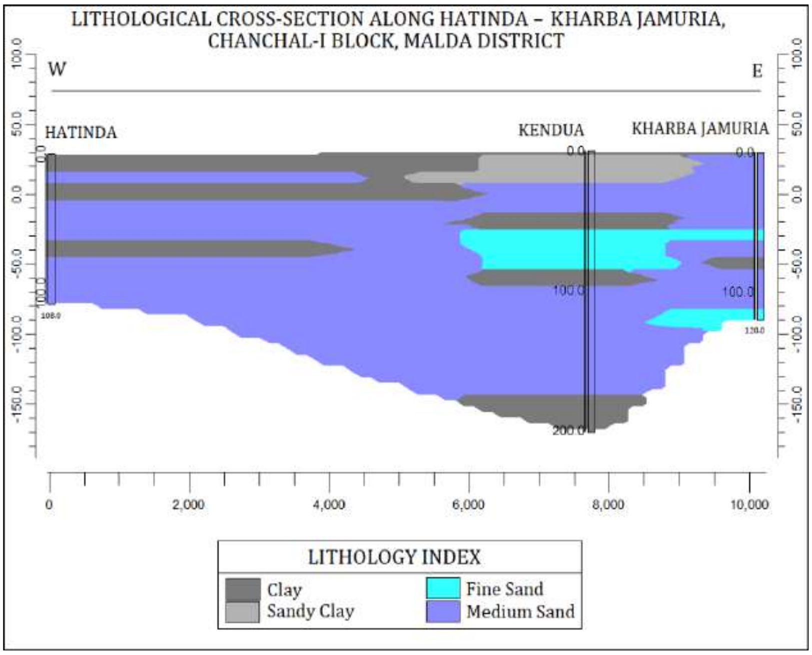


Fig. 3. Lithological cross section along West-East, Chanchal-I block

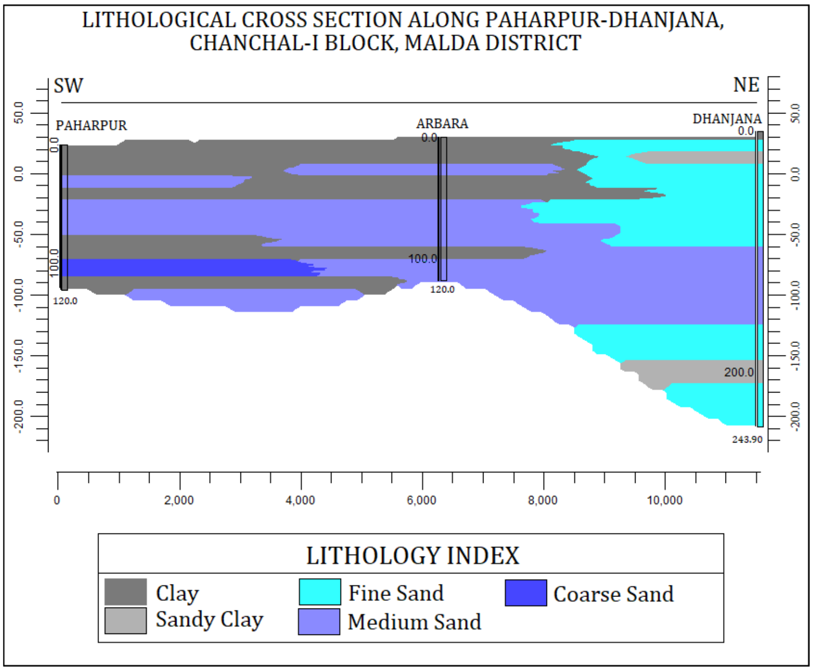


Fig. 4. Lithological cross section along SW-NE, Chanchal-I block

Status of GW Exploration

Exploratory Wells: 7
Observation Wells: 0
Piezometers: 3 (State Water Investigation Directorate/SWID)

Aquifer Characteristics

AQUIFER	DEPTH RANGE (mbgl)	THICKNESS (m)	DISCHARGE (m^3/hr)	DRAW DOWN (m)
Aquifer-I	21.0 -100.0	79.0	141.0 – 190.0	2.7 – 6.0
Aquifer-II	124.0-165.0	41.0		

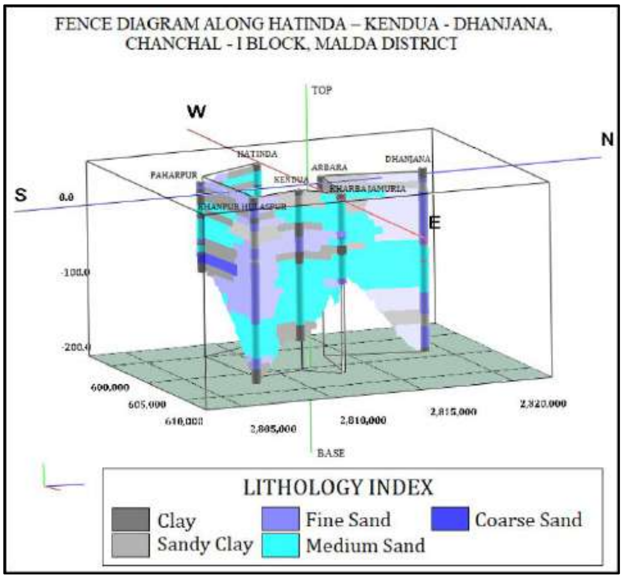


Fig. 5: Fence Diagram showing cross-correlation of lithology, Chanchal-I block

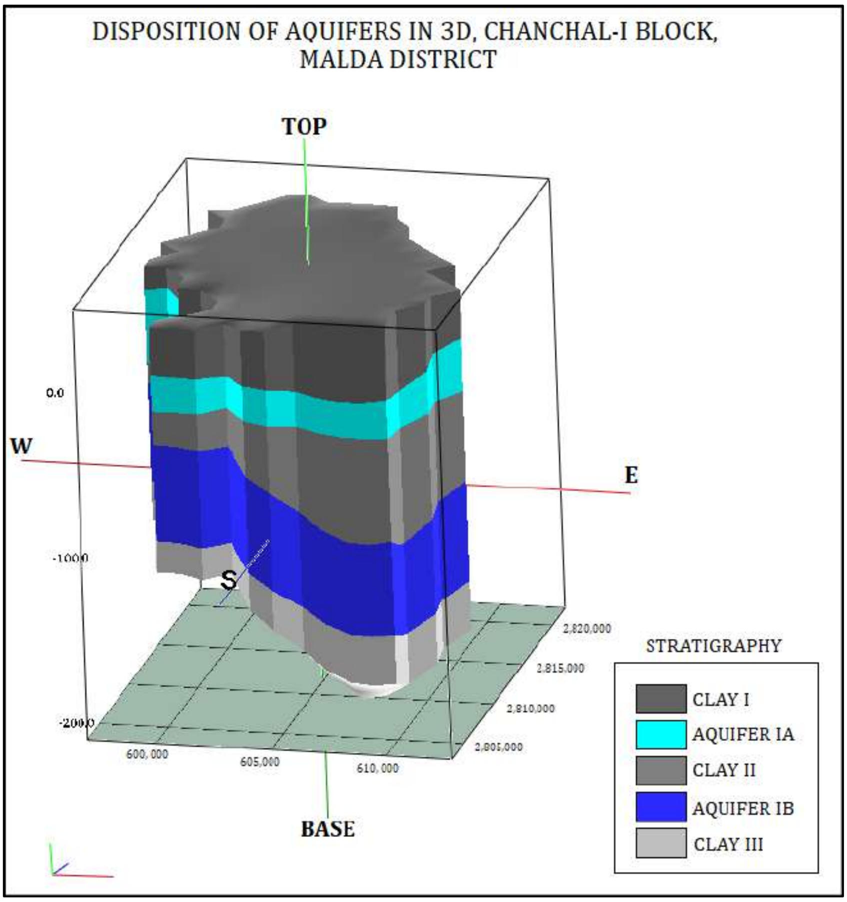


Fig. 6. Block Diagram showing aquifer disposition in 3-D, Chanchal-I block

Groundwater Monitoring Status	5 Key Observation Wells (KOW) Average DTW (pre-monsoon 2020): 6.87 m bgl Average DTW (post-monsoon 2020): 6.07 m bgl Average Water Table elevation (pre-monsoon 2020): 24.25 m Average Water Table elevation (post-monsoon 2020): 25.28 m
Groundwater Quality	*Aquifer–I and Aquifer-II: Arsenic contamination is not reported in groundwater of Chanchal-I block * NABL Data of CGWB, ER: Arsenic concentration of 0.002 mg/L was recorded in Chanchal Block Seed Farm
Aquifer Potential	The deeper aquifer (Aquifer-II) is promising, having sustainable discharge varying from 39 litre per second (lps) to 53 lps
Groundwater Resource	*Annual Extractable GW Recharge: 11022.67 ham *Total Annual GW Extraction: 6545.66 ham *Stage of GW Extraction: 59.38% *Category: Safe
Future Water Demand	*Annual GW allocation for future domestic use (up to 2042): 275.52 ham

Aquifer Management plan	
Groundwater Management Plan	**Management strategy:** 1. Rainwater harvesting, preferably open area rainwater harvesting in rural areas of Chanchal-I block. 2. Conjunctive use of surface water and ground water. 3. Two Water Supply Schemes are presently functional at Khanpur-Hulaspur and Dhanjana, both of them are based on groundwater (Source: Public Health Engineering Directorate, Govt. of West Bengal).
Artificial Recharge and Water Conservation Possibilities	1. The areas in Chanchal-I block are generally not suitable for implementing Artificial Recharge schemes according to the latest Master Plan for Artificial Recharge (CGWB 2020). 2. However, water conservation through open area rainwater harvesting in rural areas and roof top rainwater harvesting in urban areas (Chanchal) may be adopted depending on detailed micro level studies.

Aquifer Management Plan

Chanchal-II block, Malda district, West Bengal

(205.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Chanchal-II
Location	Located in the northern part of Malda district
Geographical Area	205.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Two Aquifer System, first aquifer occurring at shallow to intermediate (>60<100 m) depth and second (deeper) aquifer occurring at >100 m depth
Major Aquifer System	Younger Alluvium(Aquifer Code - AL01): Average depth range variable for Aquifer-1A and Aquifer-1B Aquifer-I: 32.0 – 96.0 m bgl Aquifer-II: 119.0 – 218.0 m bgl
Annual Rainfall	2019: 1461.0 mm, 2020: 1550.2 mm

AQUIFER DISPOSITION

Aquifer Disposition

Aquifer-I: Shallow to moderately deep aquifers with thick (>10 m) clay layers)

- Occurs throughout the block
- Aquifer material: Younger Alluvium (Holocene)

Aquifer-II: Confined aquifers (>100 m bgl & extending to >200 m bgl)

- Occurs throughout the block
- Underlain by crystalline rocks (Precambrian basement of Garo-Rajmahal Gap) at deeper levels (>300 m?)

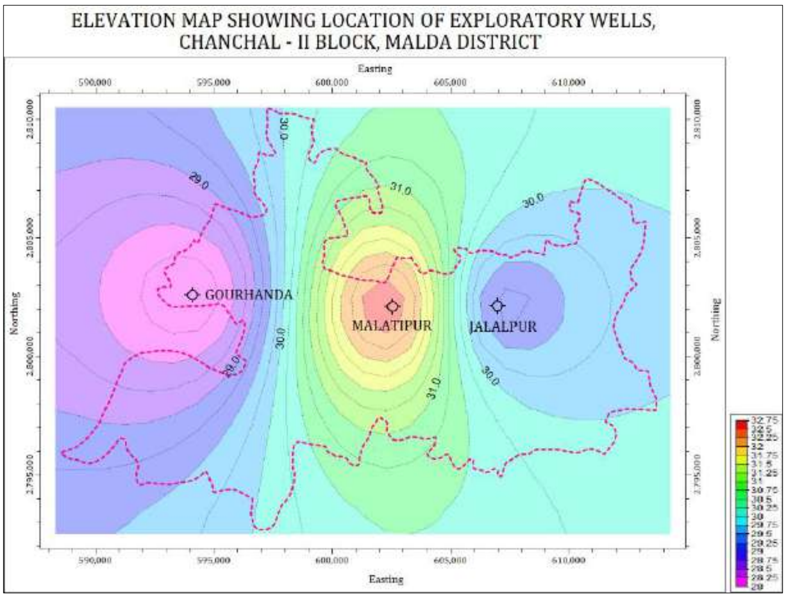


Fig. 1: Elevation map showing location of Exploratory Wells, Chanchal-II block

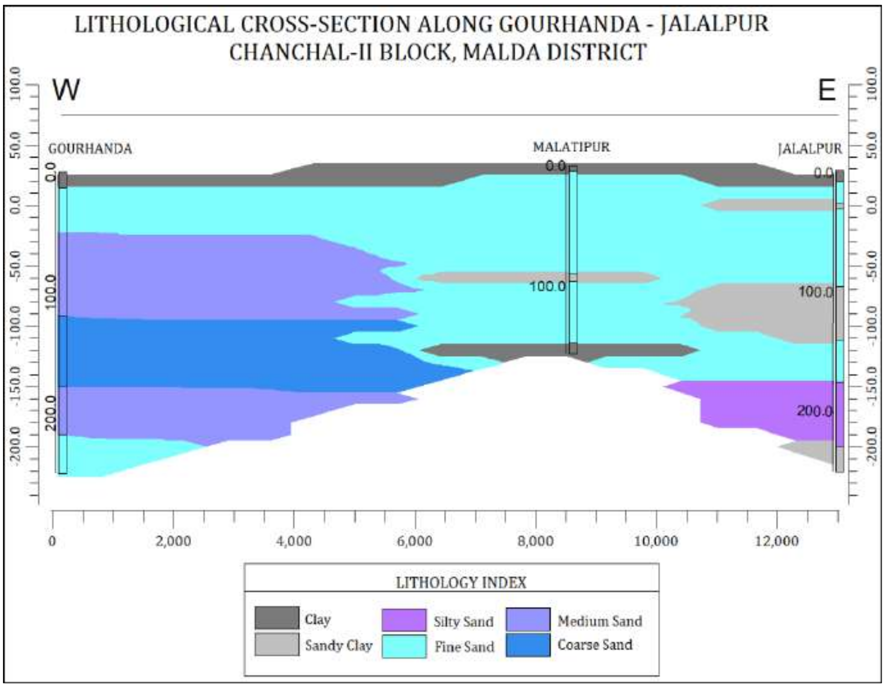


Fig. 2: Lithological cross section along W-E, Chanchal-II block

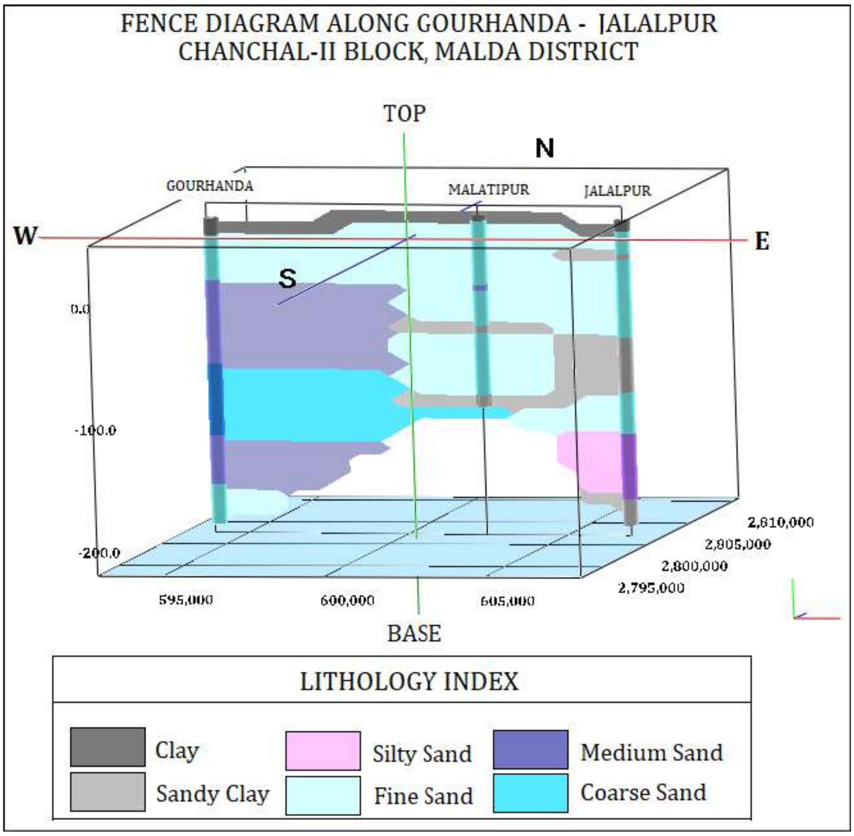
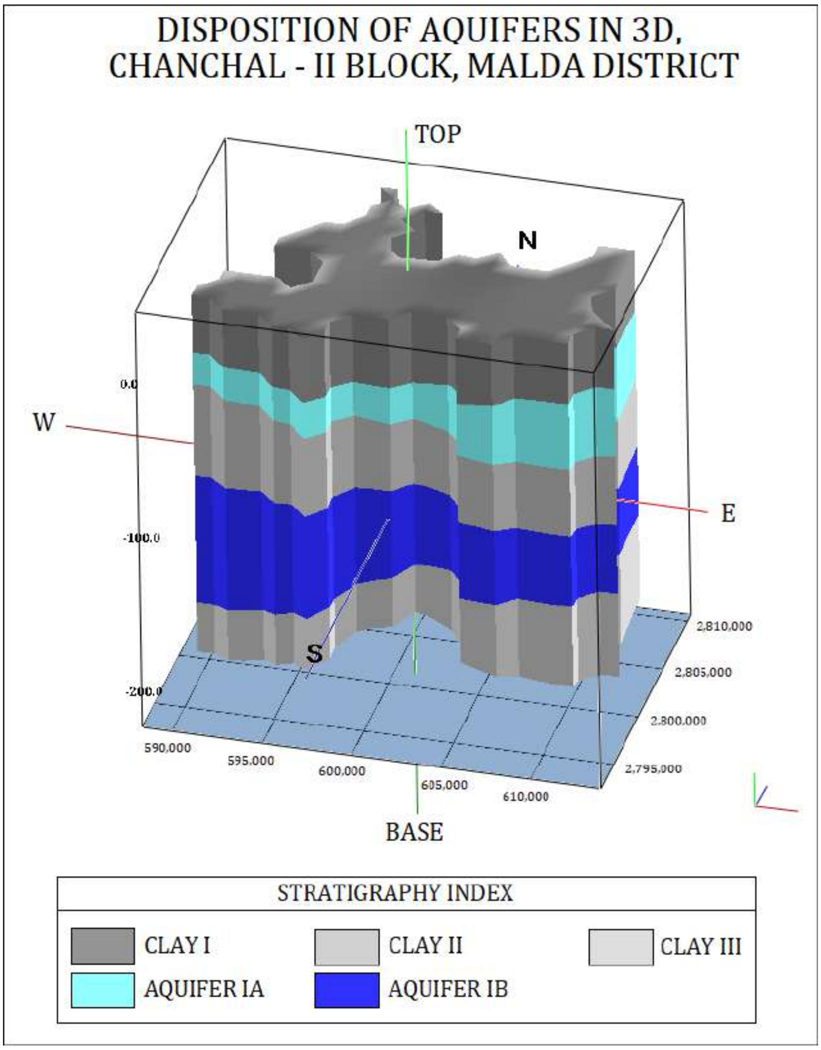


Fig. 3: Fence Diagram along Gourhanda–Malatipur-Jalalpur, Chanchal-II block

Status of GW Exploration	Exploratory Wells: 2 Observation Wells: 3 Piezometers: 3 (State Water Investigation Directorate/SWID)
Aquifer Characteristics	 **Fig. 4. Block Diagram showing aquifer disposition in 3-D, Chanchal-II block**
Groundwater Monitoring Status	3 monitoring wells Average DTW (pre-monsoon 2020): 7.03 m bgl Average DTW (post-monsoon 2020): 6.63 m bgl Average Water Table elevation (pre-monsoon 2020): 19.97 m Average Water Table elevation (post-monsoon 2020): 20.37 m
Groundwater Quality	➢ Aquifer–I: Arsenic contamination reported in only one habitation (Arsenic>0.01<0.05 mg/L) as per Report of Arsenic Task Force, Govt. of West Bengal. ➢ NABL Data of CGWB, ER: Arsenic concentration in groundwater was found to be varying from Traces (BDL) at Malatipur, 0.0001 mg/L at Kandaran and 0.001 mg/L at Jalalpur ➢ Aquifer-II: The deeper aquifer is free from Arsenic contamination

Aquifer Potential

AQUIFER	DEPTH RANGE (mbgl)	THICKNESS (m)	DISCHARGE (m^3/hr)	DRAW DOWN (m)
Aquifer-I	32.0 - 96.0	64.0	188.0 – 232.0	1.5 – 5.0
Aquifer-II	119.0 – 218.0	99.0		

Groundwater Resource

*Annual Extractable GW Recharge: 16366.18 ham

*Total Annual GW Extraction: 11384.68 ham

*Stage of GW Extraction: 69.56%

*Category: Safe

Future Water Demand

*Annual GW allocation for future domestic use (up to 2042): 277.59 ham

Aquifer Management plan

Groundwater Management Plan

Problem 1: Ground water contamination caused by arsenic in younger Alluvium of Aquifer-I (shallow to moderately deep aquifers).

Block	**Arsenic (<0.01 mg/L)**		**Arsenic (>0.01<0.05 mg/L)**		**Arsenic (>0.05 mg/L)**		**No. of Tube Wells with high Arsenic (maximum As concentration)**
	%	**Count**	**%**	**Count**	**%**	**Count**	
Chanchal-II	0	0	NA	NA	NA	NA	One (0.001 mg/L at Jalalpur)

Table showing percentage of wells having high arsenic content.

Management strategy:

1. Installation of arsenic removal plants to ensure supply of potable water from Aquifer-I.
2. Rainwater harvesting, especially open area rainwater harvesting in rural areas.
3. Conjunctive use of surface water and ground water.
4. Alternate cropping (like horticulture instead of conventional paddy cultivation) to be adopted to eliminate bio-magnification of arsenic in food grains.
5. Two Water Supply Schemes (groundwater based) at Gourhanda and Jalalpur are functional (Source: Public Health Engineering Directorate, Govt. of West Bengal).

Artificial Recharge & Conservation Possibilities

1. The areas in Chanchal-II block are generally not suitable for implementing Artificial Recharge schemes according to the latest Master Plan for Artificial Recharge (CGWB 2020).
2. However, water conservation through open area rainwater harvesting in rural areas may be adopted depending on detailed village level (need based) survey.

Aquifer Information and Management System
Bamongola block, Malda district, West Bengal
(206.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Bamongola
Location	Located in the north eastern part of Malda district
Geographical Area	206.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Single Aquifer System occurring at intermediate (>60 but <150 m) and moderately deep (>150 but <200 m) levels
Major Aquifer System	Older Alluvium(Aquifer Code-AL03):Average depth range variable for Aquifer-1A and Aquifer-1B Aquifer-1A: 30.0– 63.0 m bgl Aquiufer-1B: 128.0 – 163.0m bgl
Annual Rainfall	2019: 1457.2 mm, 2020: 1701.3 mm

AQUIFER DISPOSITION

Aquifer Disposition

Aquifer-I: Confined aquifers (moderately deep aquifers with thick (>10 m) clay layers) developed in Older Alluvium of Barind Tract

- Occurs throughout the block
- Underlain by hard crystalline rocks (Precambrian basement of Garo-RajmahalGap) at deeper levels (>300 m?)
- Aquifer material: Older Alluvium (Quaternary age)

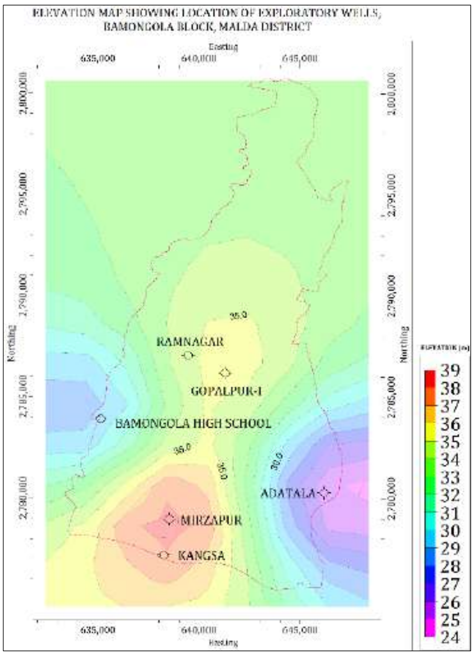


Fig. 1: Elevation map showing location of Exploratory Wells, Bamongola block

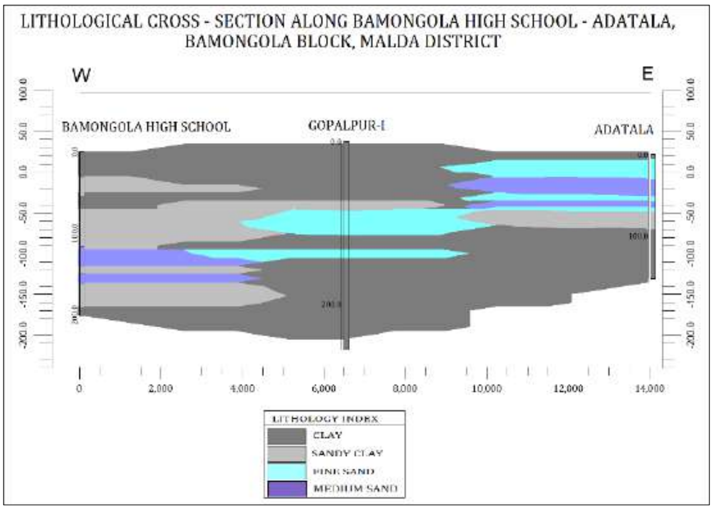


Fig. 2: Lithological cross section along W-E, Bamongola block

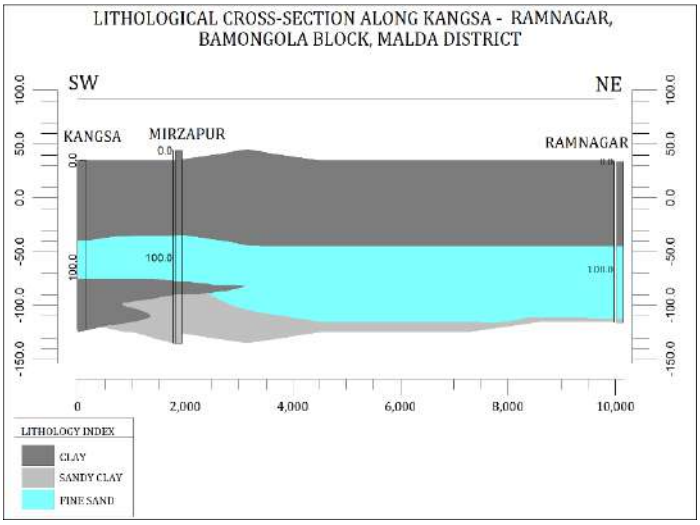


Fig. 3: Lithological cross section along SW-NE, Bamongola block

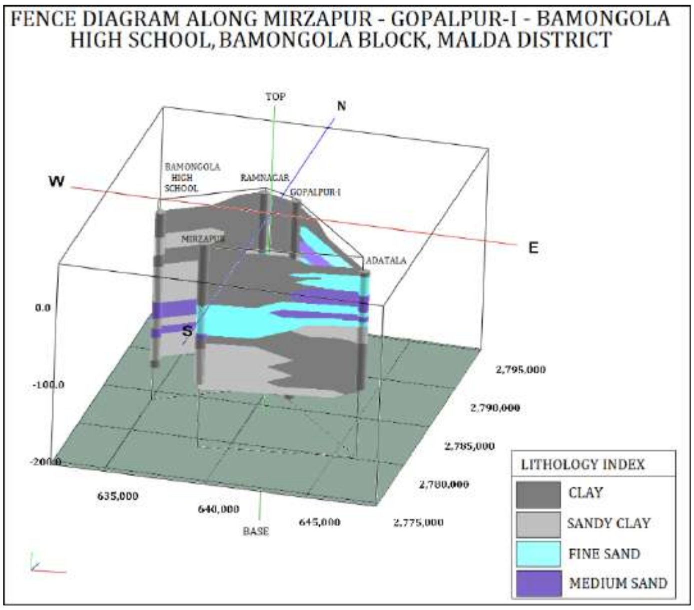


Fig. 4: Fence Diagram along Mirzapur-Gopalpur-Bamongola, Bamongola block

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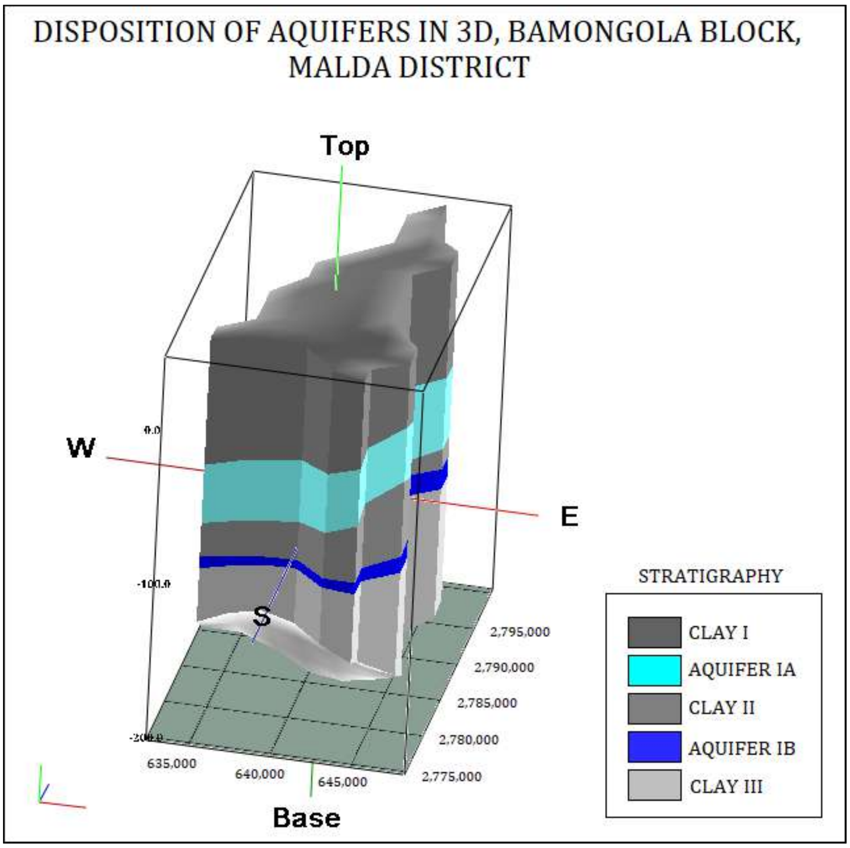
<tr><td></td><td>

Fig. 5: Block Diagram showing aquifer disposition in 3-D, Bamongola block</td></tr>
<tr><td>Status of GW Exploration</td><td>Exploratory Wells: 6
Observation Wells: 0
Piezometers: 3 (CGWB &State Water Investigation Directorate)</td></tr>
<tr><td>Aquifer Characteristics</td><td>
<table>
<tr><th>AQUIFER</th><th>DEPTH RANGE (mbgl)</th><th>THICKNESS (m)</th><th>DISCHARGE (m³/hr)</th><th>DRAW DOWN (m)</th></tr>
<tr><td>Aquifer-IA</td><td>30.0 – 63.0</td><td>33.0</td><td rowspan="2">10.0 – 40.0</td><td rowspan="2">6.0 – 12.0</td></tr>
<tr><td>Aquifer-IB</td><td>128.0-163.0</td><td>35.0</td></tr>
</table>
</td></tr>
<tr><td>Groundwater Monitoring Status</td><td>3 monitoring wells
Average DTW (pre-monsoon 2020): 1.88m bgl
Average DTW (post-monsoon 2020): 1.58bgl
Average Water Table elevation (pre-monsoon 2020):31.52m
Average Water Table elevation (post-monsoon 2020): 30.42m</td></tr>
<tr><td>Groundwater Quality</td><td>➢ Arsenic contamination wasnot reported in Bamongola block.
➢ NABL Data of CGWB, ER: Arsenic concentration was below the Acceptable Limit at various locations e.g. Bamongola (0.0001</td></tr>
</table>

	mg/L), Paikpara (0.0003 mg/L), Nalagola (0.0004 mg/L), Charakdanga (0.0005 mg/L) & Khiripara/Makuli (0.001 mg/L). High magnesium (>30 mg/L) was observed at Paikpara (51 mg/L) and Bamongola (63 mg/L). Fluoride concentration of 1.25 mg/L was recorded at Charakdanga, which is above the Permissible Limit (1.0 mg/L).
Aquifer Potential	Aquifers in Bamongola block have limited groundwater potential. Data of CGWB indicates that the sustainable discharge was variable from 3 litre per second (lps) to 11 lps.
Groundwater Resource	*Annual Extractable GW Recharge: 8154.53 ham *Total Annual GW Extraction: 1098.66ham *Stage of GW Extraction: 13.47 % *Category: Safe
Future Water Demand	*Annual GW allocation for future domestic use (up to 2042): 223.69 ham
Aquifer Management plan	
Groundwater Management Plan	**Problem 1**: Ground water contamination caused by fluoride in younger Alluvium of Aquifer-I (single aquifer system). High fluoride concentration in groundwater was reported in few tube wells of Bamongolablock. As per NABL data (CGWB, ER) fluoride concentration above the maximum permissible limit was observed at Charakdanga (1.25 mg/L). **Management strategy:** 1. Rainwater harvesting, especially open area rainwater harvesting in the rural areas. 2. Conjunctive use of surface water and ground water. 3. In areas affected with high fluoride concentration in groundwater, either fluoride removal filter plants neec to be established or water supply schemes based on surface water need to be made functional by the state government.
Artificial Recharge and Water Conservation Possibilities	1. The areas in Bamongola block are generally not suitable for implementing Artificial Recharge schemes according to the latest Master Plan for Artificial Recharge (CGWB 2020). 2. However, water conservation through open area rainwater harvesting in rural areas may be adopted depending on detailed village level (need based) survey. Roof top rainwater harvesting schemes may be implemented in urban areas (Bamongola and Pakuahat).

Aquifer Management Plan
Harishchandrapur-I block, Malda district, West Bengal
(171.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Harishchandrapur-I
Location	Located in north western part of Malda district
Geographical Area	171.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Single Aquifer System occurring at shallow (<60 m) to intermediate (>60 but <120 m) depth
Major Aquifer System	Younger Alluvium (Aquifer Code-AL01): Average depth range variable for Aquifer-1A, Aquifer-1B& Aquifer-1C. Aquifer-1A: 12.0– 43.0 m bgl Aquifer-1B: 35.0 – 83.0m bgl Aquifer-1C: 101.0 – 162.0 m bgl (limited occurrence)
Annual Rainfall	2019: 1446.2 mm, 2020: 1631.3 mm

AQUIFER DISPOSITION

Aquifer Disposition

Aquifer Group I: Mostly confined aquifers (shallow to moderately deep) with thick (>10 m) clay layers, developed in a special geomorphic unit locally known as "Tal".

- Occurs throughout the block
- Underlain by hard crystalline rocks (Precambrian basement of Garo-Rajmahal gap) at deeper levels (>300 m?)
- Aquifer material: Younger Alluvium (Holocene)

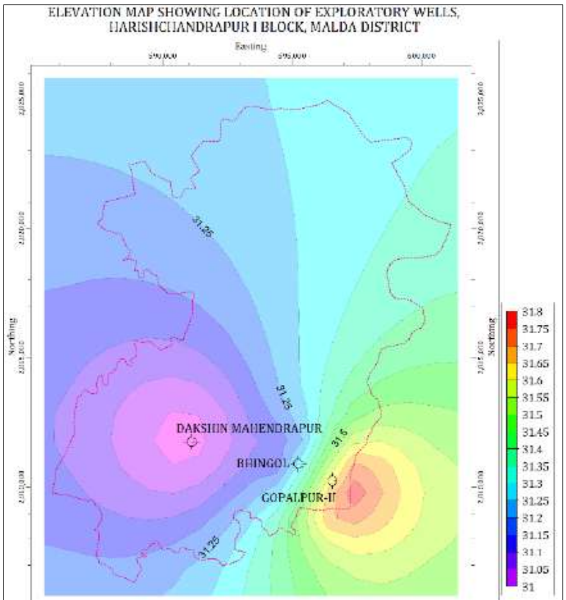


Fig. 1: Elevation map showing location of Exploratory Wells, Harishchandrapur-I block

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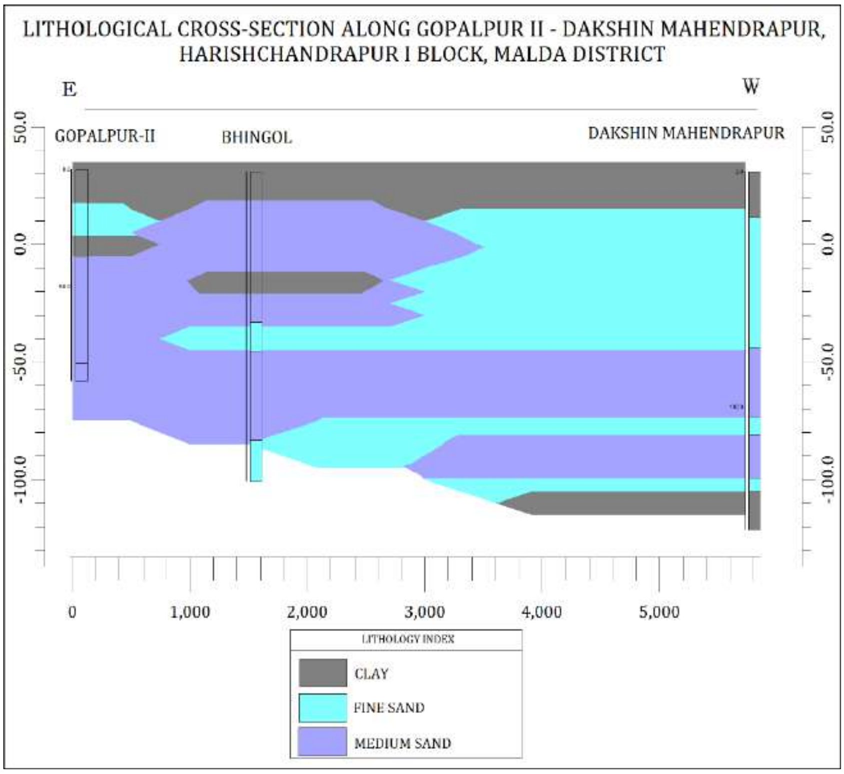


Fig. 2: Lithological cross section along E-W, Harishchandrapur-I block
</td></tr>
<tr><td>Status of GW Exploration</td><td>Exploratory Wells: 3
Observation Wells: 0
Piezometers: 3 (State Water Investigation Directorate, SWID)</td></tr>
<tr><td>Aquifer Characteristics</td><td>
<table>
<tr><th>AQUIFER</th><th>DEPTH RANGE (mbgl)</th><th>THICKNESS (m)</th><th>DISCHARGE (m³/hr)</th><th>DRAW DOWN (m)</th></tr>
<tr><td>Aquifer-IA</td><td>12.0 – 43.0</td><td>31.0</td><td rowspan="3">188.0</td><td rowspan="3">5.3 7.0</td></tr>
<tr><td>Aquifer-IB</td><td>35.0 - 83.0</td><td>48.0</td></tr>
<tr><td>Aquifer-IC</td><td>101.0 - 162.0</td><td>61.0</td></tr>
</table>
</td></tr>
<tr><td>Groundwater Monitoring Status</td><td>2 monitoring wells and 2 Key Observation Wells (KOW)
Average DTW (pre-monsoon 2020): 4.62 m bgl
Average DTW (post-monsoon 2020): 4.20m bgl
Average Water Table elevation (pre-monsoon 2020):24.39m
Average Water Table elevation (post-monsoon 2020): 24.81 m</td></tr>
<tr><td>Groundwater Quality</td><td>➢ Arsenic contamination was not reported in Harishchandrapur-I block.
➢ NABL Data of CGWB, ER: Arsenic concentration was below the Acceptable Limit in one tube well at Tulsihata (0.002 mg/L) but in another, marginally high Arsenic (0.015 mg/L) was reported (Arsenic Special Drive, 2015-16). High Iron (2.25 mg/L) and high Magnesium (41 mg/L) were found in a tube well at Tulsihata. Other parameters are below the Acceptable Limit as per the latest guidelines of BIS.</td></tr>
</table>

Aquifer Potential	Aquifers in Harishchandrapur-I block have good groundwater potential. Data of CGWB indicates that the sustainable discharge was 52 litre per second (CGWB 2001).
Groundwater Resource	*Annual Extractable GW Recharge: 14109.33 ham *Total Annual GW Extraction:9641.07ham *Stage of GW Extraction:68.33% *Category: Safe
Future Water Demand	*Annual GW allocation for future domestic use (up to 2042): 267.81 ham
Aquifer Management plan	
Groundwater Management Plan	**Management strategy:** 1. Rainwater harvesting, especially open area rainwater harvesting in the rural areas and roof top rainwater harvesting in semi-urban areas (Tulsihata). 2. Conjunctive use of surface water and ground water.
Artificial Recharge and Water Conservation Possibilities	1. The areas in Harishchandrapur-I block are generally not suitable for implementing Artificial Recharge schemes according to the latest Master Plan for Artificial Recharge (CGWB 2020). 2. However, water conservation through open area rainwater harvesting in rural areas may be adopted based on micro level survey.

Aquifer Management Plan
Harishchandrapur-II block, Malda district, West Bengal

(217.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Harishchandrapur-II
Location	Located in the north western part of Malda district
Geographical Area	217.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Single Aquifer System occurring at shallow (<60 m) to intermediate (>60 but <150 m) depth
Major Aquifer System	Younger Alluvium (Aquifer Code - AL01): Average depth range variable for Aquifer-1A, Aquifer-1B and Aquifer-1C Aquifer-1A: 9.0 – 102.0 m bgl Aquifer-1B: 58.0 – 151.0 m bgl Aquifer-1C (Deeper Aquifer): 217.0 – 241.0 m bgl
Annual Rainfall	2019: 1446.2 mm, 2020: 1631.3 mm

AQUIFER DISPOSITION

<table>
<tr>
<td>Aquifer Disposition</td>
<td>

Aquifer-I: Semi confined to confined aquifers (shallow to moderately deep aquifers with relatively thin (< 10 m) clay layers), developed in a special geomorphic unit locally known as "Tal"

- Occurs throughout the block
- Underlain by hard crystalline rocks (Precambrian basement of Garo-Rajmahal gap) at deeper levels (>300 m?)
- Aquifer material: Younger Alluvium (Holocene)

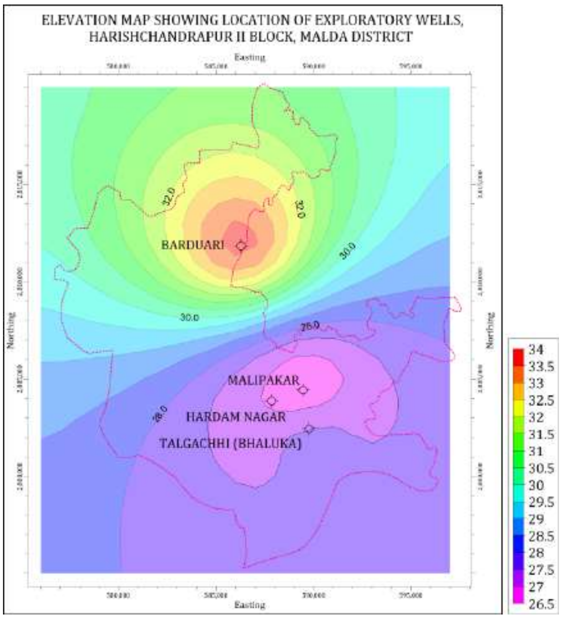


Fig. 1. Elevation map showing location of Exploratory Wells

</td>
</tr>
</table>

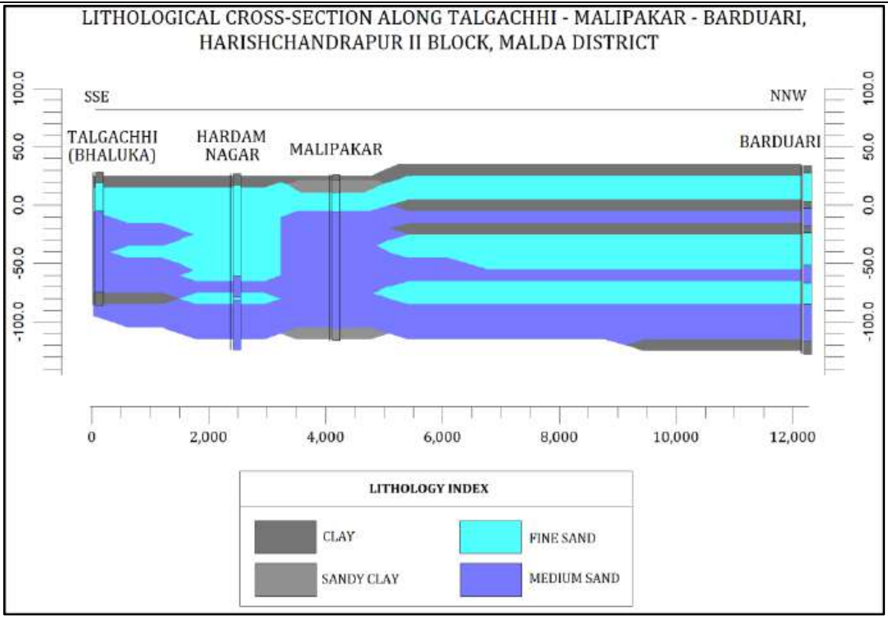


Fig. 2: Lithological cross section along NNW-SSE, Harishchandrapur-II block

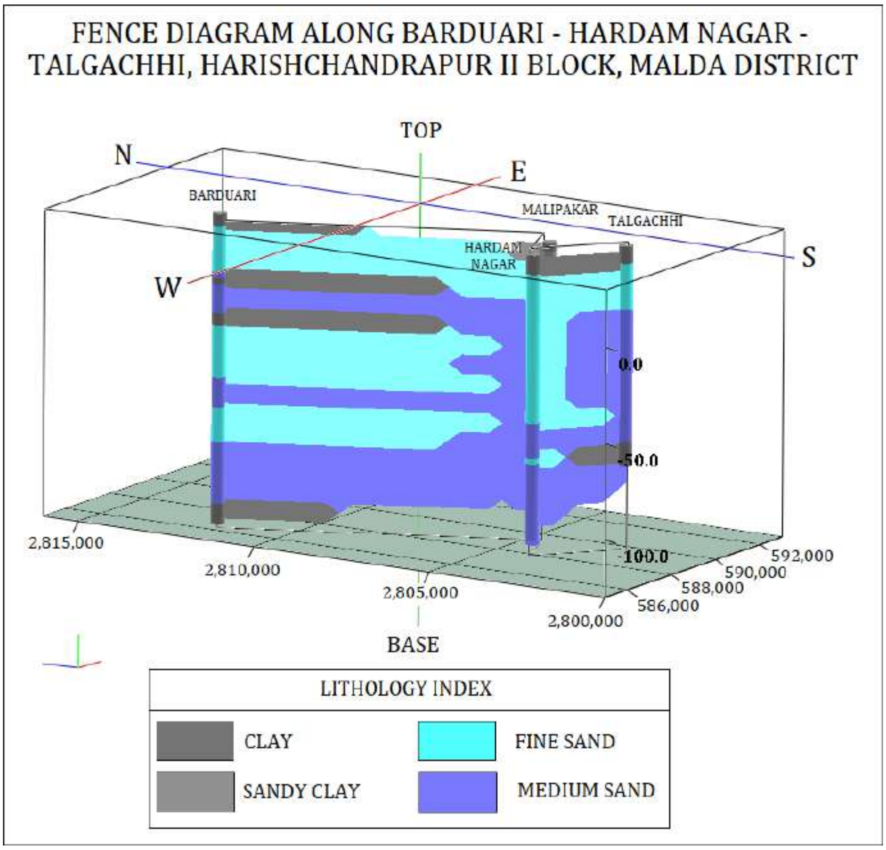


Fig. 3. Fence diagram along Barduari-Talgachhi, Harishchandrapur-II block

Status of GW Exploration	Exploratory Wells: 5 Observation Wells: 0 Piezometers: 3 (State Water Investigation Directorate (SWID)

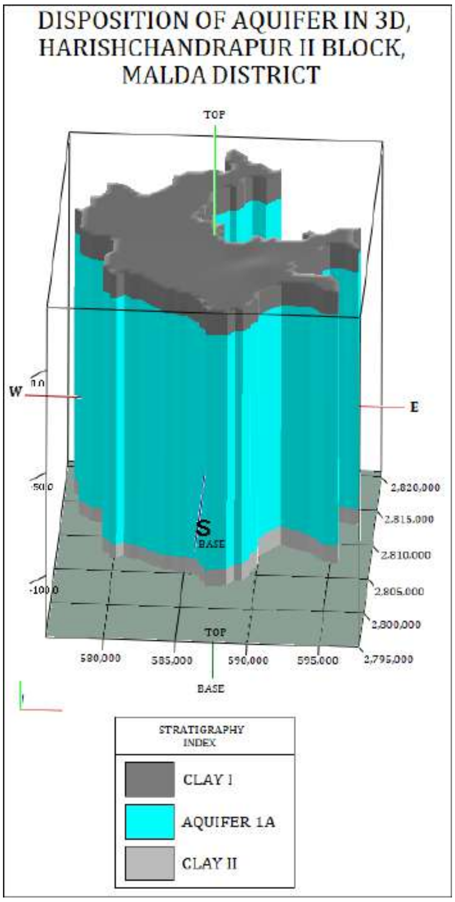
<table>
<tr><td>Aquifer Characteristics</td><td>
<table>
<tr><th>AQUIFER</th><th>DEPTH RANGE (mbgl)</th><th>THICKNESS (m)</th><th>DISCHARGE (m³/hr)</th><th>DRAW DOWN (m)</th></tr>
<tr><td>Aquifer-IA</td><td>9.0 – 102.0</td><td>93.0</td><td rowspan="2">125.0 – 197.0</td><td rowspan="2">4.2 – 7.5</td></tr>
<tr><td>Aquifer-IB</td><td>58.0-151.0</td><td>93.0</td></tr>
<tr><td>Aquifer-IC</td><td>217.0-241.0</td><td>24.0</td><td>108.0</td><td>5.8 – 6.3</td></tr>
</table>


Fig. 4. Block Diagram showing disposition of aquifer in 3-D, Harishchandrapur-II block
</td></tr>
<tr><td>Groundwater Monitoring Status</td><td>3 monitoring wells
Average DTW (pre-monsoon 2020): 6.01m bgl
Average DTW (post-monsoon 2020): 4.76 m bgl
Average Water Table elevation (pre-monsoon 2020): 24.65 m
Average Water Table elevation (post-monsoon 2020): 25.90 m</td></tr>
<tr><td>Groundwater Quality</td><td>➢ Arsenic contamination was not reported in Harishchandrapur-II block.
➢ NABL Data of CGWB, ER: Arsenic concentration was below the Acceptable Limit at Barduary (0.003 mg/L). Other parameters were also below the Acceptable Limit as per the latest guidelines of BIS.</td></tr>
<tr><td>Aquifer Potential</td><td>Aquifers in Harishchandrapur-II block have good groundwater potential. Data of CGWB indicates that the sustainable discharge in tube wells was varying from 35 litre per second (lps) to 55 lps.</td></tr>
</table>

<table>
<tr><td>Groundwater Resource</td><td>*Annual Extractable GW Recharge: 19728.70 ham
*Total Annual GW Extraction: 13350.82 ham
*Stage of GW Extraction: 67.67 %
*Category: Safe</td></tr>
<tr><td>Future Water Demand</td><td>*Annual GW allocation for future domestic use (up to 2042): 343.68 ham</td></tr>
<tr><td colspan="2">Aquifer Management plan</td></tr>
<tr><td>Groundwater Management Plan</td><td><u>Management strategy</u>:
1. Rainwater harvesting, especially open area rainwater harvesting in the rural areas.
2. Conjunctive use of surface water and ground water.</td></tr>
<tr><td>Artificial Recharge and Water Conservation Possibilities</td><td>1. The areas in Harishchandrapur-II block are generally not suitable for implementing Artificial Recharge schemes according to the latest Master Plan for Artificial Recharge (CGWB 2020).
2. However, water conservation through open area rainwater harvesting in rural areas may be adopted based on micro level survey.</td></tr>
</table>

Aquifer Management Plan

Habibpur block, Malda district, West Bengal

(396.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Habibpur
Location	Located in the eastern part of Malda district
Geographical Area	396.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Single Aquifer System comprising Aquifer-IA and Aquifer-IB having variable depth and thickness throughout the block. Aquifer-IA: Occurs at shallow to intermediatedepth (>60 but <150 m) Aquifer-IB: Deeper aquifer occurring in the depth range of 150 to >200 m
Major Aquifer System	OlderAlluvium(Aquifer Code- AL03):Average depth range variable for the single Aquifer System Aquifer-IA: 32.0– 127.0m bgl Aquifer-IB: >150 to 210.0 m bgl
Annual Rainfall	2019: 1193.8mm, 2020: 1579.4 mm

AQUIFER DISPOSITION

Aquifer Disposition	**Aquifer-IA**: Confined aquifers (shallow to moderately deep aquifers) with very thick (>30 m) clay layers • Occurs throughout the block • Aquifer material: Older Alluvium (Quaternary)

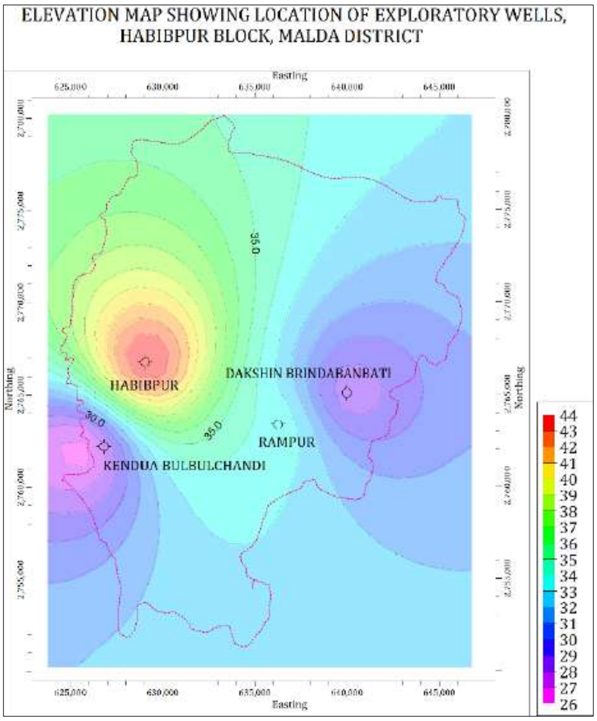


Fig. 1: Elevation map showing location of Exploratory Wells, Habibpur block

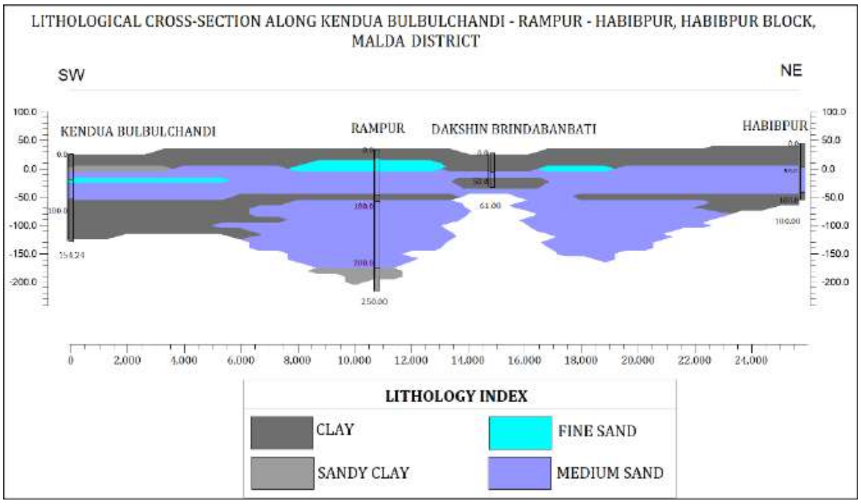


Fig. 2: Lithological cross section along SW-NE, Habibpurblock

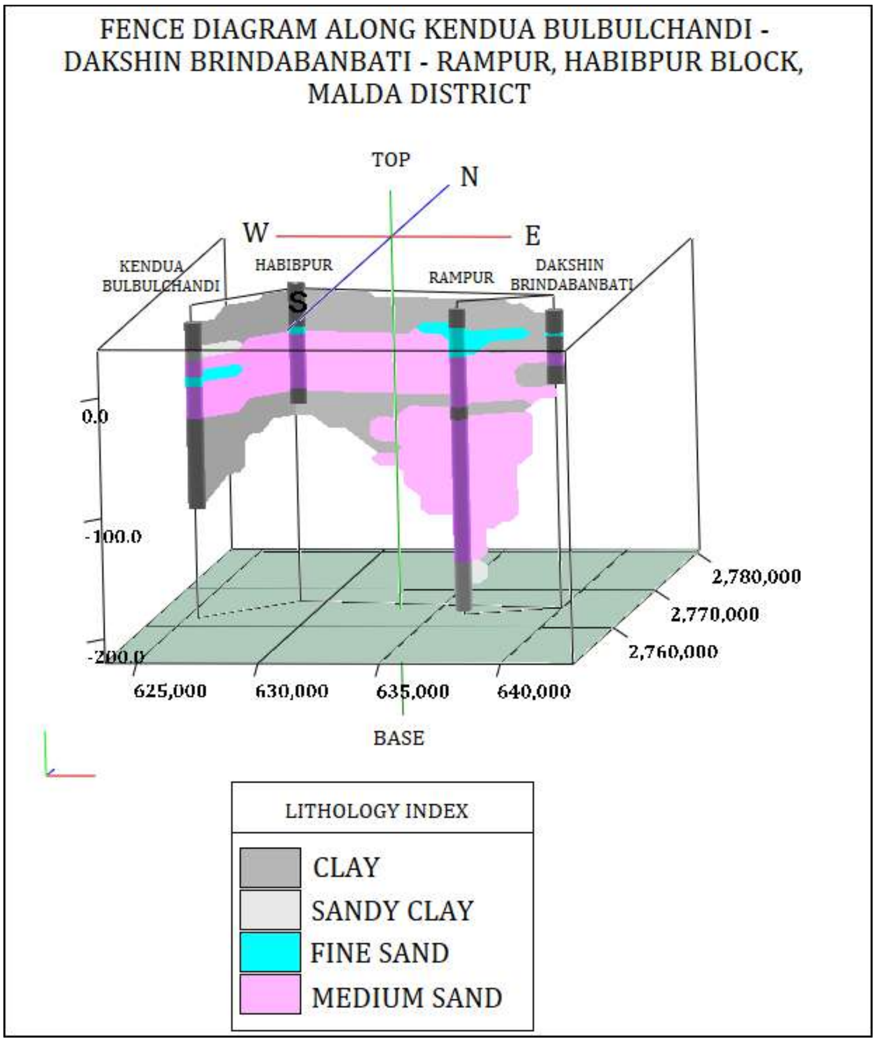


Fig. 3: Fence Diagram along KenduaBulbulchandi – Habibpur-Dakshin Brindabanbati, Habibpur block

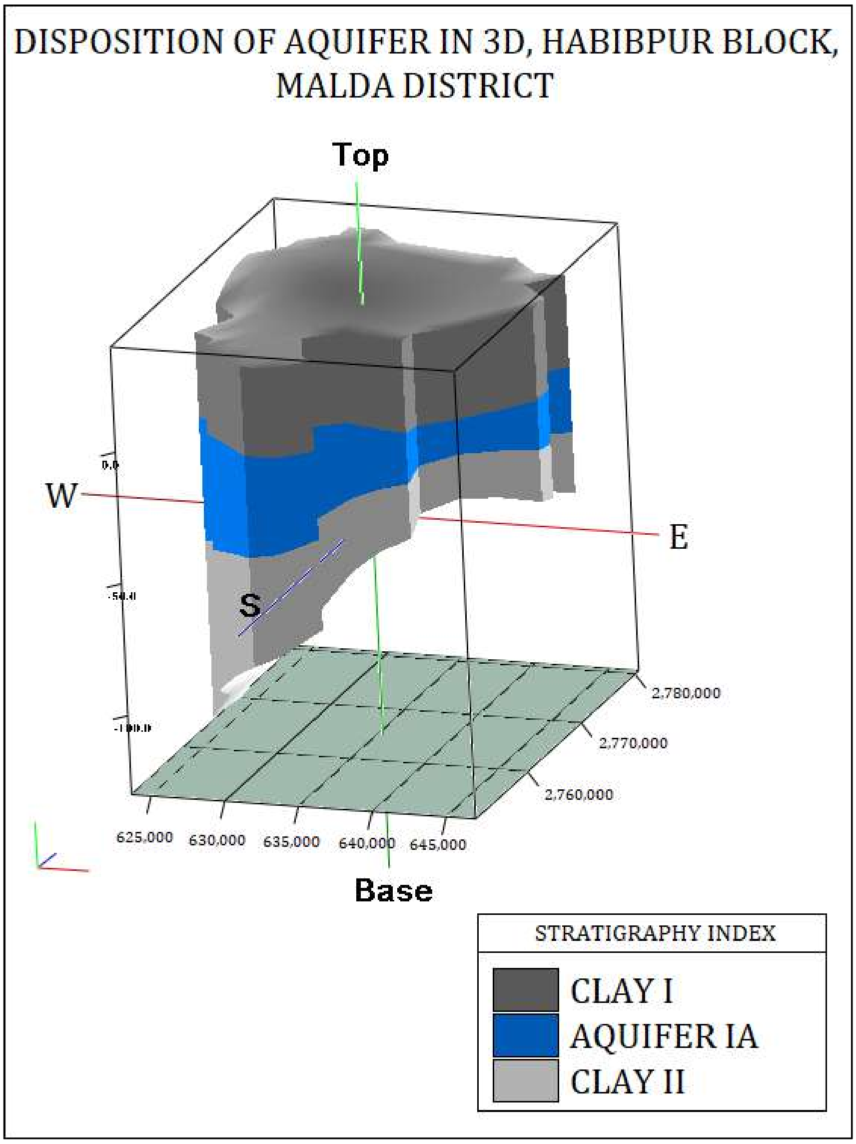
<table>
<tr><td></td><td>

Fig. 4: Block diagram showing aquifer disposition in 3-D, Habibpur block</td></tr>
<tr><td>Status of GW Exploration</td><td>Exploratory Wells: 2
Observation Wells: 1
Piezometers: 2 (State Water Investigation Directorate)</td></tr>
<tr><td>Aquifer Characteristics</td><td>
<table>
<tr><th>AQUIFER</th><th>DEPTH RANGE (mbgl)</th><th>THICKNESS (m)</th><th>DISCHARGE (m^3/hr)</th><th>DRAW DOWN (m)</th></tr>
<tr><td>Aquifer-IA</td><td>32.0 – 127.0</td><td>95.0</td><td rowspan="2">46.0 – 47.7</td><td rowspan="2">6.0</td></tr>
<tr><td>Aquifer-IB</td><td>>150.0 – 210.0</td><td>60.0</td></tr>
</table>
</td></tr>
<tr><td>Groundwater Monitoring Status</td><td>5 monitoring wells (including 3 Key Observation Wells)
Average DTW (pre-monsoon 2020): 12.51m bgl</td></tr>
</table>

	Average DTW (post-monsoon 2020): 9.89 m bgl Average Water Table elevation (pre-monsoon 2020): 20.16m Average Water Table elevation (post-monsoon 2020): 22.78m
Groundwater Quality	➢ Arsenic contamination has not been reported in Habibpur block. ➢ NABL Data of CGWB, ER: Arsenic concentration in groundwater was found to be varying from Traces (Below Detection Limit) to 0.0003 mg/L at Habibpur and 0.001 mg/L at Kokabeni/Tajpur (Arsenic Special Drive, 2016 and NAQUIM studies, 2020).
Aquifer Potential	Aquifers in Habibpur block generally have good groundwater potential with sustainable discharge of 13 litre per second (lps), as per in house data of CGWB
Groundwater Resource (as on 31-3-2017)	*Annual Extractable GW Recharge: 11678.09ham *Total Annual GW Extraction: 4420.47ham *Stage of GW Extraction: 37.85% *Category: Safe
Future Water Demand (as on 31-3-2017)	*Annual GW allocation for future domestic use (up to 2042): 311.14 ham
Aquifer Management plan	
Groundwater Management Plan	**<u>Management strategy</u>:** 1. Rainwater harvesting especially open area rainwater harvesting in rural areas and roof top rainwater harvesting in semi-urban areas (Habibpur and Bulbulchandi). 2. Conjunctive use of surface water and ground water.
Artificial Recharge&Water Conservation Possibilities	1. Implementation of Artificial Recharge schemes in Habibpur block is generally not feasible according to the latest Master Plan for Artificial Recharge (CGWB 2020). 2. However, water conservation through open area rainwater harvesting in rural areas and through roof top rainwater harvesting in semi-urban areas should be adopted depending on local hydrometeorological conditions.

Aquifer Management Plan
Gazole block, Malda district, West Bengal
(513.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Gazole
Location	Located in the north eastern part of Malda district
Geographical Area	513.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Two Aquifer System, first aquifer occurring at shallow to intermediate i.e. <60 <150 m and second (deeper) aquifer occurring at intermediate to deeper levels (>120 and also >200 m).
Major Aquifer System	Older Alluvium (Aquifer Code - AL03): Average depth range variable for Aquifer-1A and Aquifer-1B Aquifer-IA: 50.0 – 153.0 m bgl Aquifer-IB: 128.0 – 218.0 m bgl
Annual Rainfall	2019: 1027.5 mm, 2020: 1643.6 mm

AQUIFER DISPOSITION

Aquifer Disposition

Aquifer-IA: Confined aquifers (shallow to moderately deep aquifers) with thick (>10 m) clay layers

- Occurs throughout the block
- Aquifer material: Older Alluvium (Quaternary)

Aquifer-IB: Confined aquifers at deeper levels (>100 m bgl and extending to >200 m bgl)

- Occurs throughout the block
- Underlain by hard crystalline rocks (Precambrian basement of Garo-Rajmahal Gap) at deeper levels (>300 m?)

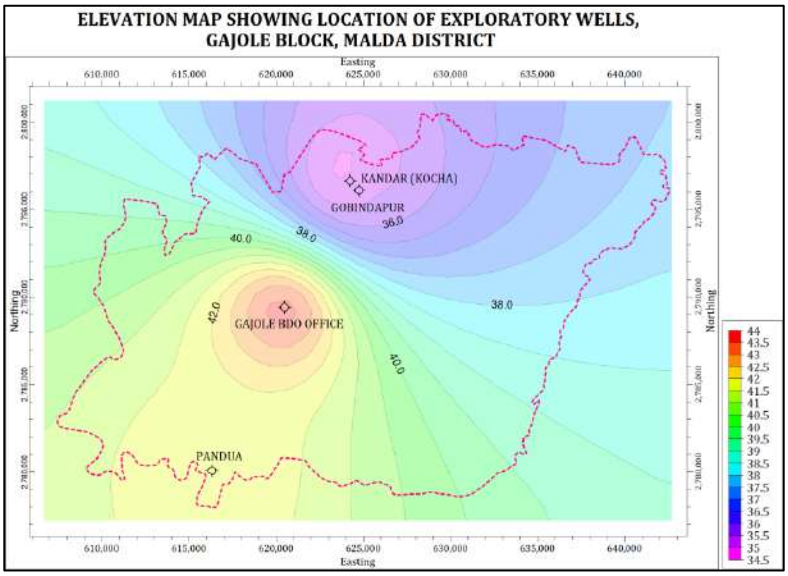


Fig. 1: Elevation map showing location of Exploratory Wells, Gazole block

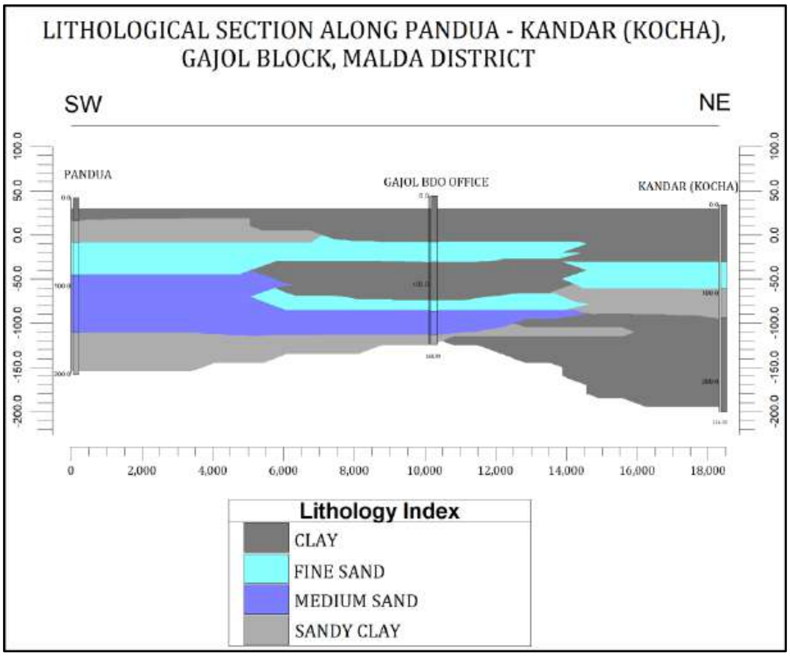


Fig. 2: Lithological cross section along SW-NE, Gazole block

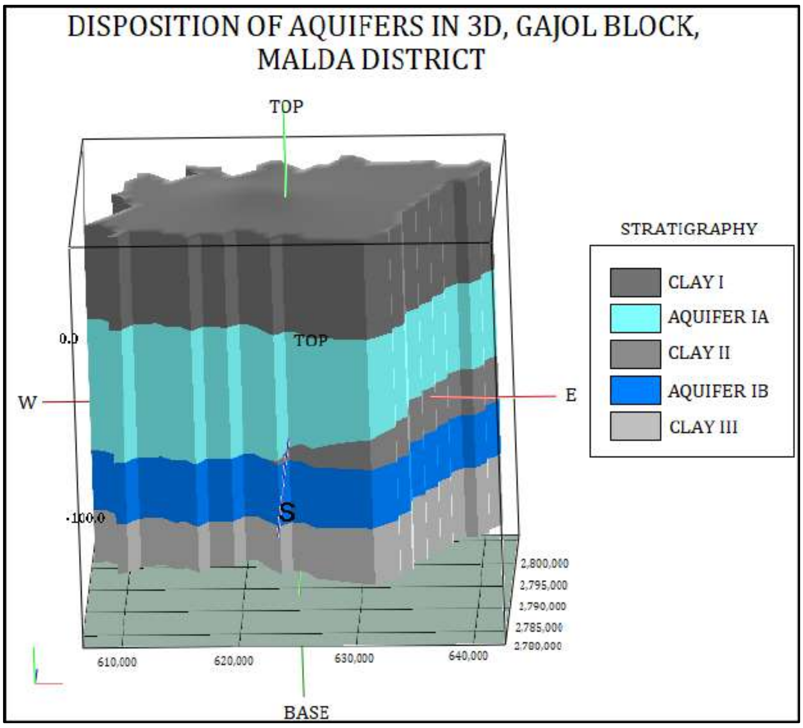


Fig. 3: Block Diagram showing aquifer disposition in 3-D, Gazole block

Status of GW Exploration	Exploratory Wells: 4 Observation Wells: 0 Piezometers: 6 (CGWB & State Water Investigation Directorate)

<table>
<tr><td>Aquifer Characteristics</td><td>
<table>
<tr><th>AQUIFER</th><th>DEPTH RANGE (mbgl)</th><th>THICKNESS (m)</th><th>DISCHARGE (m^3/hr)</th><th>DRAW DOWN (m)</th></tr>
<tr><td>Aquifer-IA</td><td>50.0 – 153.0</td><td>103.0</td><td rowspan="2">89.0 – 247.0</td><td rowspan="2">7.0 – 12.0</td></tr>
<tr><td>Aquifer-IB</td><td>128.0 – 218.0</td><td>90.0</td></tr>
</table>
</td></tr>
<tr><td>Groundwater Monitoring Status</td><td>10 monitoring wells
Average DTW (pre-monsoon 2020): 2.15 m bgl
Average DTW (post-monsoon 2020): 1.66 m bgl
Average Water Table elevation (pre-monsoon 2020): 24.99 m
Average Water Table elevation (post-monsoon 2020): 27.59 m</td></tr>
<tr><td>Groundwater Quality</td><td>➢ Arsenic contamination has not been reported in Gazole block, except for one sporadic value of 0.082 mg/L at Ghaksole (CGWB Arsenic Special Drive, 2015-16).
➢ NABL Data of CGWB, ER: Arsenic concentration in groundwater was found to be varying from Traces (BDL) to 0.0001 mg/L at Matoil, 0.0004 mg/L at Panchamukhi & Gazole, 0.002 mg/L Pandua and 0.003 mg/L at Mashaldighi. High Magnesium (>30 mg/L) was found at Pandua (36 mg/L), Agampur (51 mg/L) and Gazole (52 mg/L).</td></tr>
<tr><td>Aquifer Potential</td><td>The deeper aquifer (Aquifer-IB) has very good groundwater potential, having sustainable discharge varying from 25 litre per second (lps) to 69 lps.</td></tr>
<tr><td>Groundwater Resource</td><td>*Annual Extractable GW Recharge: 15563.62 ham
*Total Annual GW Extraction: 7881.88 ham
*Stage of GW Extraction: 50.64 %
*Category: Safe</td></tr>
<tr><td>Future Water Demand</td><td>*Annual GW allocation for future domestic use (up to 2042): 485.56 ham</td></tr>
<tr><td colspan="2">Aquifer Management plan</td></tr>
<tr><td>Groundwater Management Plan</td><td><u>Management strategy</u>:
1. Rainwater harvesting, especially open area rainwater harvesting in rural areas and roof top rainwater harvesting in semi-urban areas (Gazole).
2. Conjunctive use of surface water and ground water.</td></tr>
<tr><td>Artificial Recharge & Water Conservation Possibilities</td><td>1. Schemes for Artificial Recharge techniques may be adopted in Gazole block.
2. Recharge techniques should be adopted on priority in areas having post-monsoon depth to water level > 9 m bgl, and with long-term declining trend.
3. Using standard parameters in Master Plan for Artificial Recharge (CGWB, 2020), the calculations show:</td></tr>
</table>

	- Volume of surface runoff = 0.086 MCM - Surface water requirement = 0.230 MCM - Unsaturated Aquifer volume (suitable for Artificial Recharge) = 1.535 MCM - Priority area for implementing Artificial Recharge = 0.255 km^2

Aquifer Management Plan
Old Malda block, Malda district, West Bengal
(217.0 km² area covered under NAQUIM)

GENERAL INFORMATION

State Name	West Bengal
District name	Malda
Block Name	Old Malda
Location	Located in the south-central part of Malda district
Geographical Area	217.0 km²
Basin/Sub-basin	Ganga/ Bhagirathi
Principal Aquifer System	Alluvium (Code - AL) Single Aquifer System comprising Aquifer-IA and Aquifer-IB having variable depth and thickness throughout the block. Aquifer-IA: Occurs extensively at shallow depth (<60 m) Aquifer-IB: Relatively deeper aquifer occurring in shallow to intermediate depth range (from <60 m to <150 m)
Major Aquifer System	OlderAlluvium(Aquifer Code- AL03):Average depth range variable for the single Aquifer System comprising Aquifer-IA & Aquifer-IB Aquifer-IA: 19.0– 44.0m bgl Aquifer-IB:48.0 – 134.0 m bgl
Annual Rainfall	2019: 1136.7mm, 2020: 1361.0 mm

AQUIFER DISPOSITION

Aquifer Disposition	**Aquifer-IA**: Confined aquifers (shallow to moderately deep) withthick (>10 m) clay layers • Occurs throughout the block • Aquifer material: Older Alluvium (Quaternary) • Underlain by Precambrian Basement (granite gneiss) at 213 m bgl (at observed in Exploratory Well at Mandilpur)

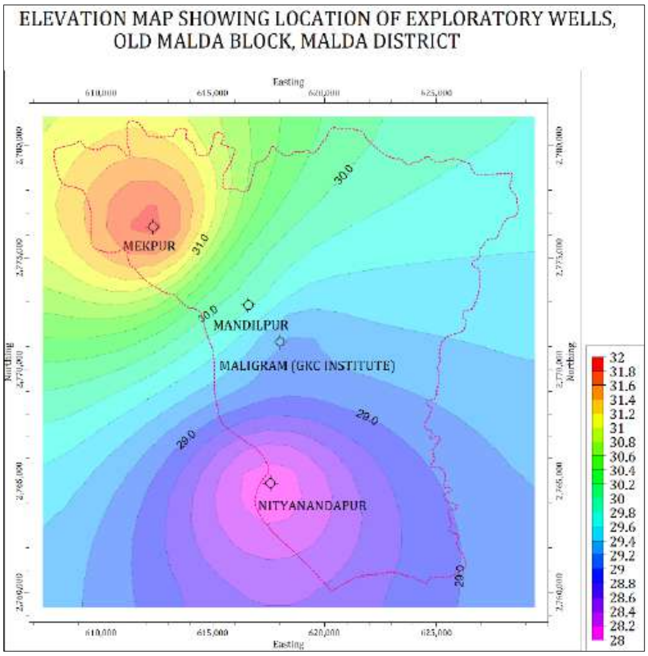


Fig. 1: Elevation map showing location of Exploratory Wells, Old Maldablock

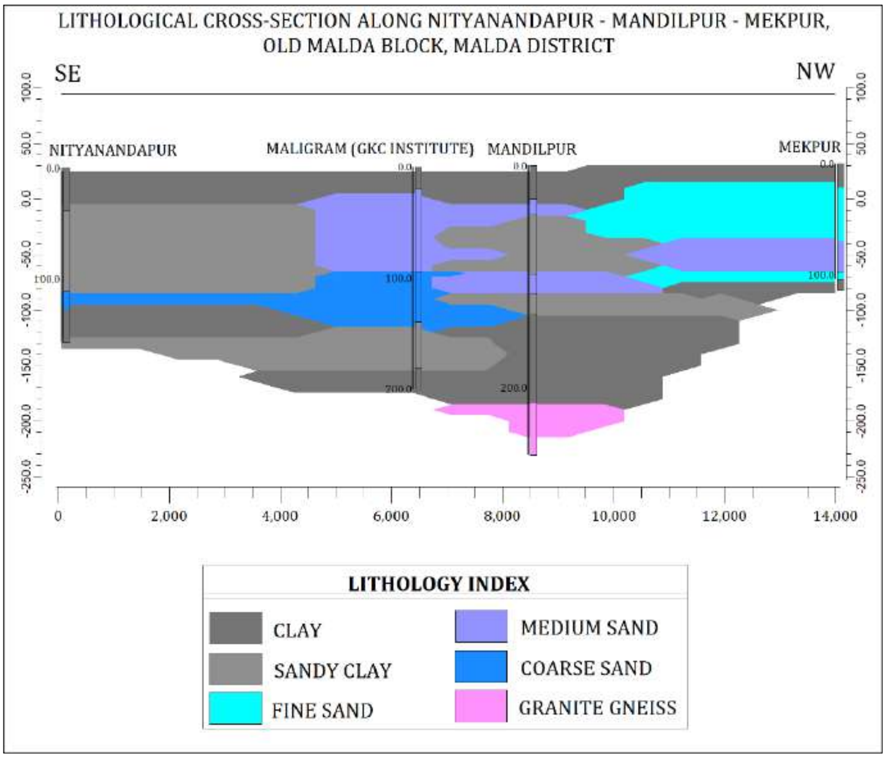


Fig. 2: Lithological cross section, Old Malda block

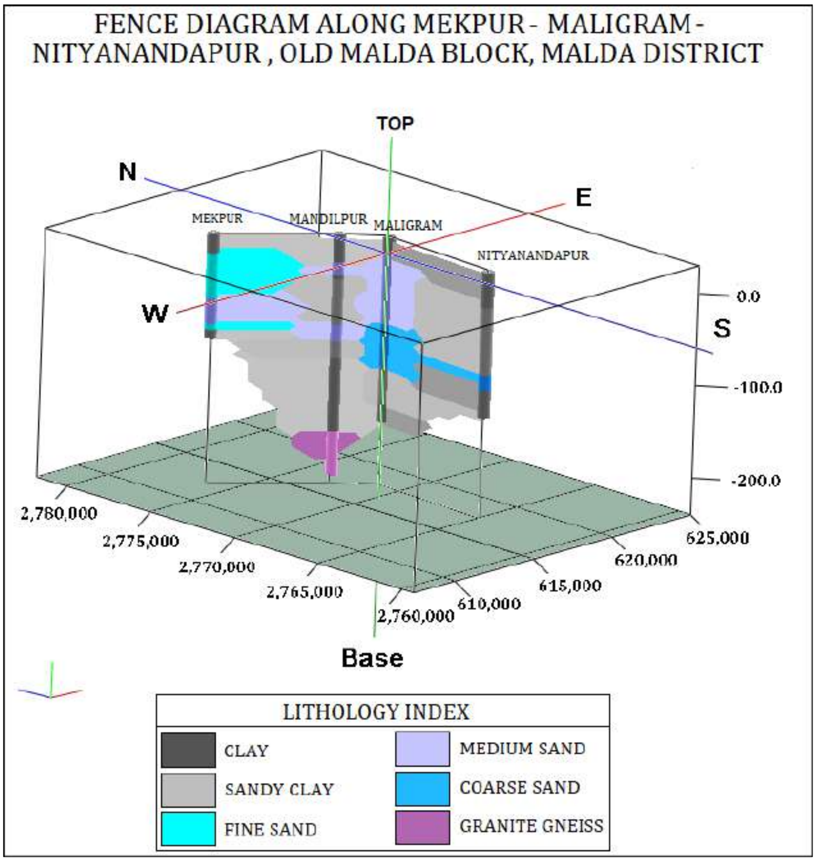
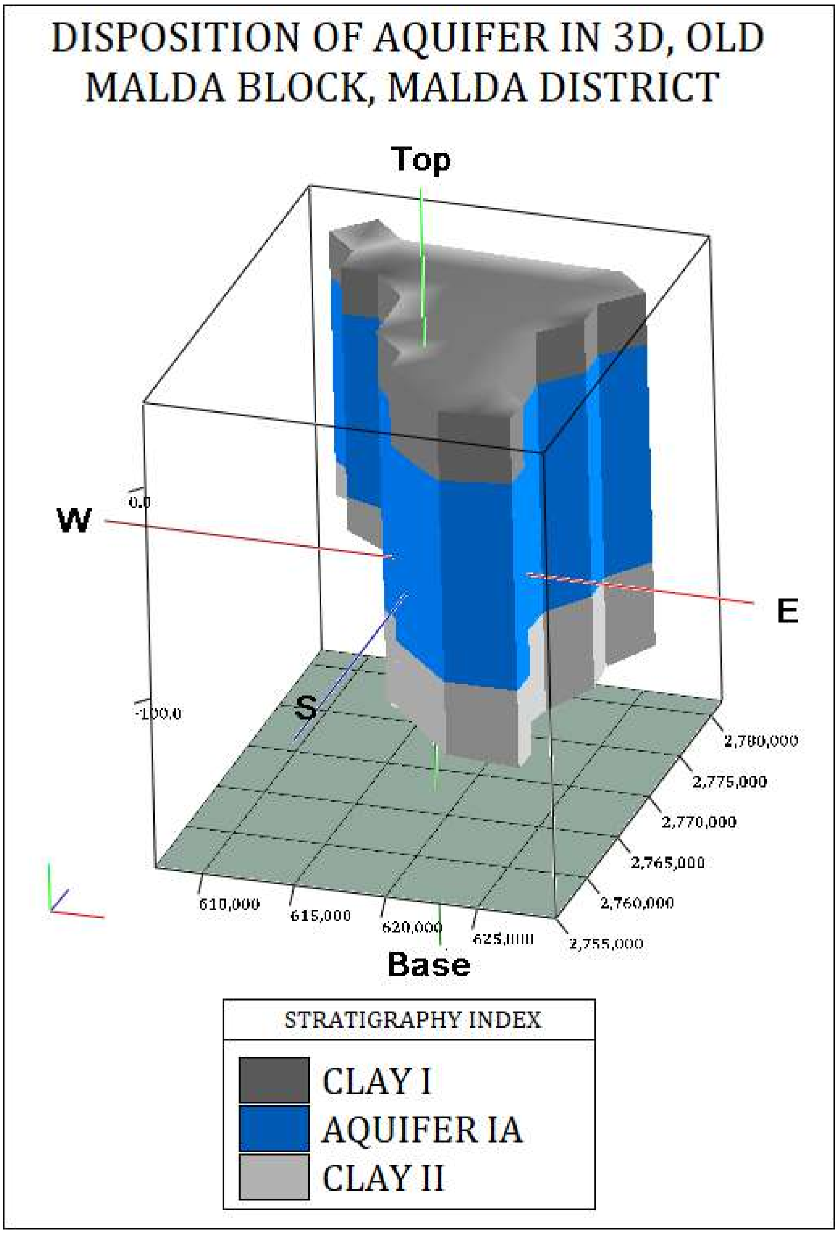


Fig. 3: Fence diagram along Mekpur-Mamdilpur-Maligram-Nityanandapur, Old Malda block

	 **Fig. 4: Lithological cross section, Old Malda block**
Status of GW Exploration	Exploratory Wells: 3 Observation Wells: 0 Piezometers: 2 (State Water Investigation Directorate (SWID)

<table>
<tr><td>Aquifer Characteristics</td><td>
<table>
<tr><th>AQUIFER</th><th>DEPTH RANGE (mbgl)</th><th>THICKNESS (m)</th><th>DISCHARGE (m^3/hr)</th><th>DRAW DOWN (m)</th><th>TRANSMISSIVITY (m^2/day)</th></tr>
<tr><td>Aquifer-IA</td><td>19.0 – 44.0</td><td>25.0</td><td rowspan="2">135 - 259</td><td rowspan="2">7.0 – 11.0</td><td rowspan="2">2969.0</td></tr>
<tr><td>Aquifer-IB</td><td>48.0 – 134.0</td><td>86.0</td></tr>
</table>
</td></tr>
<tr><td>Groundwater Monitoring Status</td><td>5 monitoring wells (including 1 Key Observation Well)
Average DTW (pre-monsoon 2020):4.40m bgl
Average DTW (post-monsoon 2020):2.39 m bgl
Average Water Table elevation (pre-monsoon 2020):21.60 m
Average Water Table elevation (post-monsoon 2020): 25.37 m</td></tr>
<tr><td>Groundwater Quality</td><td>➢ Arsenic contamination has not been reported in Old Maldablock.
➢ NABL Data of CGWB, ER:Arsenic concentration in groundwater was found to be varying fromTraces (BDL) to 0.0003 mg/L at Habibpur and 0.001 mg/L at Kokabeni/Tajpur (Arsenic Special Drive of CGWB, 2015-16).</td></tr>
<tr><td>Aquifer Potential</td><td>Aquifers in Old Malda block have good groundwater potential with sustainable discharge varying from 38 litre per second (lps) to 72 lps.</td></tr>
<tr><td>Groundwater Resource</td><td>*Annual Extractable GW Recharge: 9613.44 ham
*Total Annual GW Extraction: 5170.64 ham
*Stage of GW Extraction: 53.79%
*Category: Safe</td></tr>
<tr><td>Future Water Demand</td><td>*Annual GW allocation for future domestic use (up to 2042): 349.24 ham</td></tr>
<tr><td colspan="2">Aquifer Management plan</td></tr>
<tr><td>Groundwater Management Plan</td><td><u>Management strategy</u>:
1. Rainwater harvesting especially open area rainwater harvesting in rural areas and roof top rainwater harvesting in urban and semi-urban areas (Malda Town, Mangalbari and Sahapur).
2. Conjunctive use of surface water and ground water.</td></tr>
<tr><td>Artificial Recharge&Water Conservation Possibilities</td><td>1. As per the Master Plan on Artificial Recharge (CGWB 2020), an insignificant area of 0.022 km^2 is the recharge worthy area. Volume of unsaturated aquifer available for Artificial Recharge is 0.132 MCM.
2. However, water conservation through open area rainwater harvesting in rural areas may be adopted depending on detailed micro level survey.</td></tr>
</table>

9. CONCLUSION AND RECOMMENDATIONS

9.1 CONCLUSION

Malda district is located in the southernmost part of North Bengal, with Ganga River at Farakka flowing along its southern boundary. The district is bounded by latitudes $24^0$40'20" N to $25^0$32'08" and longitudes $87^0$45'50" E to $88^0$28'10" E. An area of 3733 km^2 was covered during Aquifer Mapping and Management study in the AAP: 2019-20 and 2020-21. The salient points of the study are given below:

- Malda district is flanked by Ganga River on its western and southwestern boundary. It is bounded by Pakur district (Jharkhand) in the west, by Purnea district (Bihar) in the northwest, by Uttar Dinajpur and Dakshin Dinajpur district in the north and northeast, by Murshidabad district in the south and by the international border with Bangladesh on the east and southeast.
- Double cropping is usually practiced with cropping intensity of 196.0%. Flood plain area (*Diara*) is the most fertile land. Net sown area in the district is 2343.19 km^2 with a very low cultivable waste land. Forest land is very less (16.79 km^2) without any permanent pasture and other grazing land. Principal crops grown in the district include paddy (*Aus, Aman* and *Boro*), potato, wheat, various types of pulses, mustard and other oilseeds, jute, sugarcane and other *Rabi* crops.
- The area under groundwater irrigation is 917.39 km^2, which is irrigated with a total of 34185 heavy duty, medium duty and low duty tube wells.
- Southwest monsoon is the main source of rainfall. Normal rainfall in the district is 1453 mm. Average annual number of rainy days (daily rainfall $\geq$ 2.5 mm) was 67. In 2020, the highest monthly rainfall was 346.5 mm in July whereas the lowest was 8.3 mm in January.
- Three major geomorphological types in the district are Barind, Diara and Tal. Eastern part of the district, comprising mainly Older Alluvium, is known as the *Barind* Tract. Younger and Older alluvial plains are locally known as '*Diara*'. '*Tal*' is the swampy interfluves exposed between Mahananda and Kalindri rivers in northern part of the district.
- Source of surface water in the district is mainly from the perennial rivers, tanks, water bodies (*bils*) and numerous small ponds. Ganga, Mahananda, Kalindri, Tangon and Punarbhaba Rivers are the major natural drainage in the district.
- Geological setting of the district is a result of shallow subsidence and deposition of Ganga alluvium in the Garo-Rajmahal Gap. Large-scale sedimentation by the Himalayan Rivers caused deposition of Older Alluvium of Pleistocene age and Younger Alluvium of Holocene age.

- Main water bearing formations are Quaternary alluvial sediments (Older Alluvium and Younger Alluvium) comprising sands of varying grades, silt and clay with occasional gravels. Due to facies variation during basin evolution, aquifer geometry is not regular. Sub-surface lithological data indicates that top clay layer has a thickness varying from 3 m to 15 m. Top clay is thinner in northern, eastern and central parts and relatively thicker in the eastern part of the district. This layer is underlain by sands of variable grain size and thickness (10 to 30 m) and occasionally hard rock (granite gneiss, metavolcanics) in depth range >130 m at Araidanga (Ratua-II block), Mandilpur (Old Malda block) and Narendrapur (English Bazar block).
- Generally, potential aquifers exist in depth range of 17 m to 178 m. Preparation of block wise aquifer maps have indicated that two major aquifer systems have developed viz. Aquifer-1A and Aquifer-1B, except in Habibpur, Old Malda and Harishchandrapur-II blocks where only Aquifer-1A has been developed. Aquifer-1A occurs under unconfined condition in the depth range of ~25 to ~70 m whereas Aquifer-1B occurs under semi-confined to confined condition in the depth range of ~90 to ~180 m.
- Coarse sand and gravel constitutes potential aquifers down to ~90 m depth in the eastern part and down to ~180 m depth in the central and western parts of Malda district. Aquifer geometry and architecture at deeper levels (>250 m to ~400 m depth) needs to be deciphered through deep groundwater exploration.
- Thickness of the aquifers varies widely from place to place. In-house drilling data indicates Static Water Level varying from 5.44 m bgl at Bhaluka to 19.90 m bgl at Nityanandapur. Discharge of tube wells was varying from 626.40 m^3/day at Bhaluka (Ratua-I block) to 5034.53 m^3/day at Mandilpur (Old Malda block). Drawdown was ranging from 1.11 m at Bhaluka to 9.84 m at Nityanandapur. Transmissivity was ranging from 207.81 m^2/day at Narendrapur (English Bazar block) to 7170.0 m^2/day at Araidanga (Ratua-II block). Storage Co-efficient of aquifer in the depth range of 81 to 105 m was 9.9 x 10^{-2}at Araidanga, thereby indicating semi-confined nature of the aquifer.
- Analysis of seasonal fluctuation in groundwater level (year: 2020) has indicated that 59 wells out of 72 (81.94% of total) had shown seasonal rise in groundwater level whereas 13 wells (18.06% of total) had recorded seasonal decline. The decadal (long-term) fluctuation was done using decadal mean (2010 to 2019) and data of 2020. The analysis indicates that in pre-monsoon, 34 wells out of 36 (94.44% of total) have recorded decadal rise. In post-monsoon, decadal analysis in 40 monitoring wells has indicated that 36 wells (90% of total) show decadal rise in groundwater level. The analysis also reveals absence of long-term decline in groundwater level.

➢Assessment of Dynamic Groundwater Resources (as on 31-3-2013) reveals that total groundwater recharge was 150784.98 ham, whereas existing gross groundwater draft for all uses was 65501.03 ham. Net annual groundwater availability was 136087.61 ham whereas allocation for future domestic and industrial water supply was 9828.37 ham. Stage of Groundwater Development was 48.13% with 13 out of 15 blocks falling under "Safe" category. Habibpur and Harishchandrapur-I blocks were categorized as "Semi Critical" blocks following the GEC-1997 methodology.

- Based on Vertical Electrical Sounding (VES) in Habibpur block (Barind Tract), coarse sand was interpreted as a promising aquifer in the depth range 26-85 m and 130-200 m. In Manikchak block, weathered basalt and coarse sand were identified as promising aquifers in the depth range of 30-80 m, which is prone to arsenic contamination. From VES data, the recommended drilling depth was interpreted between 40 and 180 m.
- Chemical analysis of groundwater indicated high arsenic (>0.01 mg/L) in English Bazar, Manikchak, Ratua-I, Ratua-II, Chanchal-II, Kaliachak–I, Kaliachak-II and Kaliachak-III blocks (Arsenic Task Force, Govt. of West Bengal). Sporadically high arsenic also identified in Old Malda, Gazole and Harishchandrapur-I block. During the Arsenic Special Drive, analysis of 159 samples revealed high arsenic in 47 samples with arsenic concentration ranging from 0.215 mg/L at Mohana (Manikchak block) to 0.402 mg/L at Sujapur (Kaliachak-I block).
- According to Fluoride Task Force, Govt. of West Bengal, Bamongola and Ratua-II blocks are identified as fluoride contaminated (fluoride ≥ 1.50 mg/L). Data of CGWB has shown high fluoride at Sripur (4.54 mg/L) in Ratua-II block and marginally high fluoride at Chhoto Mohanpara (1.80 mg/L) in English Bazar block.
- High iron (>1.0 mg/L) was recorded in many locations in Malda district. Iron concentration was found to vary from 2.90 mg/L to 3.35 mg/L in Uttar Chandipur Water Supply Scheme and 1.36 mg/L in Jotgopal Scheme. Data of CGWB has revealed high iron in 10 samples out of 53 (18.87% of total) with concentration of 6.58 mg/L at Chhoto Mohanpara, 6.24 mg/L at Manikchak, 3.45 mg/L at Mahajantala, 3.17 mg/L at Bamongola, 2.03mg/L at Pandua and 1.85 mg/L at Pagla Bridge.
- Plotting of groundwater samples in Piper Trilinear Diagram and Modified Piper (Chadha) Diagram, Wilcox Diagram and U.S. Salinity Diagram has revealed that groundwater of shallow and deeper aquifers are suitable both for drinking and irrigation. Hydrochemical facies classification indicated that groundwater is of Ca-Mg-HCO_3 type.
- Groundwater originated from shallow aquifers is characterized by recharge from fresh water and major hydrochemical process is weathering-solution. Low sodium and chloride content in groundwater signifies absence of inland salinity hazard.
- Plotting of groundwater samples in Wilcox Diagram and USSL Diagram has revealed that majority of samples fall either in S1-C2 or S1-C3 class. This indicates suitability of groundwater for irrigational use.

- The outcomes of present study were shared in physical mode to Sh. Rajarshi Mitra (IAS) and District Magistrate, Malda in his office on 15th November 2021. PowerPoint presentation was made in presence of the Additional District Magistrate (General), Additional District Magistrate (Development), representatives from concerned state government departments like Public Health Engineering Directorate, Malda Division and Arsenic Area Water Supply Division, departments under the Water Resources Investigation and Development Department (WRIDD) like State Water Investigation Directorate, Water Resources Development Directorate (WRDD), Agri-irrigation Department and Agriculture Department.

9.2 RECOMMENDATIONS

Based on the outcome of the present study on Aquifer Mapping and Management, the following recommendations are suggested for an effective and scientifically sustainable management of the aquifers of Malda district:

- Conjunctive use of surface water and groundwater needs to be adopted. Cultivation of summer paddy (*Boro* rice) through numerous shallow and deep tube wells has resulted in unprecedented stress on the aquifer system. Therefore, instead of installing additional tube wells for agri-irrigation, a modification in cropping pattern should be adopted. *Boro* cultivation needs to be reduced by at least 10% of the present production.
- Crops like peanuts, sunflower, soybean and ginger needs to be grown instead of water-intensive paddy crop, especially during peak summer season. However, crop subsidy has to be given by the state government to the small and marginal farmers due to their poor socio-economic condition.
- Borehole logs are not available in Kaliachak-I, Kaliachak-II and Kaliachak-III block. Therefore, subsurface data generation through exploration is to be taken up urgently in this area. The data would help in preparation of block level Aquifer Management Plans for these blocks and aid in deciphering the depth range of arsenic contaminated aquifers in the southernmost part of Malda district.
- Due to very low stage of groundwater development (<70%) for the entire district, adoption of demand side groundwater management may not be a priority. On the other hand, supply side aquifer management is possible through implementation of rain water harvesting and managed aquifer recharge in Kaliachak-I, Gazole and Old Malda blocks, as per the available data on latest Master Plan for Artificial Recharge (CGWB 2020).
- Artificial recharge can be implemented through Percolation Tanks, Injection Wells and by Re-excavation of Existing Tanks with Recharge Shafts. Only shallow aquifer (Aquifer-1A) in the depth range of ~25 to ~30 m is suitable for artificial recharge. Except three blocks,

scope of artificial recharge is negligible due to presence of thick (>10 m) clay layers.

- There is very good potential for water conservation through rainwater harvesting due to high Normal Rainfall (1453 mm) in Malda district. Possibility of implementing roof top rain water harvesting in urban and peri-urban areas (Malda Town, Gazole, Chanchal, Ratua, Harishchandrapur, Manikchak, Habibpur) and open area rain water harvesting in rural areas may be explored.
- Estimation of non-committed surface run off for water conservation through rain water harvesting has indicated that 22.5% of total surface runoff in Malda district can be utilized for rain water harvesting. Highest availability of non-committed surface runoff exists in Gazole block and lowest in Kaliachak-I block. Accordingly, given the existing fund position, prioritization can be done by the district administration for implementation of pilot projects at block level.
- Based on Monsoon Rainfall (1219.8 mm in 2020), volume of water available for implementing rainwater harvesting in 27 Census Towns is estimated at 0.003 MCM with an estimated cost of twelve lakh rupees. In two Municipal Bodies (English Bazar and Old Malda), the estimated rainwater volume for rainwater harvesting is 0.015 MCM with an estimatedcost of forty lakh rupees.
- Depending on the local socio-economic condition, it is prudent to adopt participatory ground water management at village and community level.
- There is a growing need to involve the village and community through programmes like Public Interaction Programme, which was organized through Google Meet platform on 28th July 2021. In this programme, the outcomes of the aquifer mapping and management study in Malda district was shared to representatives from state government departments, academic institutes, farmers, social workers and students of the district. More such programmes may be taken up in a phased manner in block headquarters of all fifteen community development blocks of the district for generating better impact on the importance of sustainable groundwater management through participatory approach at village and community level.
- This was followed by a presentation of the Aquifer Mapping Study in Malda district in the office of the District Magistrate, Malda (in physical mode) on 15th November 2021.
- For an effective conservation of rainwater and groundwater, various state government and central government aided schemes need to be implemented in a phased manner. Examples of such schemes include the *Jal Dhoro Jal Bhoro* programme by the Government of West Bengal, Pradhan Mantri Krishi Sinchai Yojana – Har Khet Ko Pani (PMKSY-HKKP) project and Jal Shakti Abhiyan (Phase-I and II) of the Ministry of Jal Shakti and the Ministry of Rural Development, Government of India.

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FIELD PHOTOGRAPHS

Ground Water Monitoring being carried out during NAQUIM study at Haldar Para, Habibpur block, Malda district

Measurement of water level in Key Observation Well established at Kanua, Chanchal-I block, Malda district during NAQUIM study (AAP: 2020-2021)

Water Treatment Plant of Public Health Engineering Directorate (PHED), Govt. of West Bengal at Dariapur, Kaliachak-III block. The plant is used for removal of Arsenic and also for rural water supply in Kaliachak-I, Kalaichak-II, Kalaichak-III and Manikchak blocks, Malda district

Inside view of Arsenic Removal cum Water Treatment Plant (PHED, GoWB) at Dariapur, Kaliachak-III block, Malda district

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