केन्द्रीय भूमि जल बोर्ड

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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

PARTS OF PURBA MEDINIPUR District, West Bengal

पूर्वी क्षेत्र, कोलकाता

Eastern Region, Kolkata

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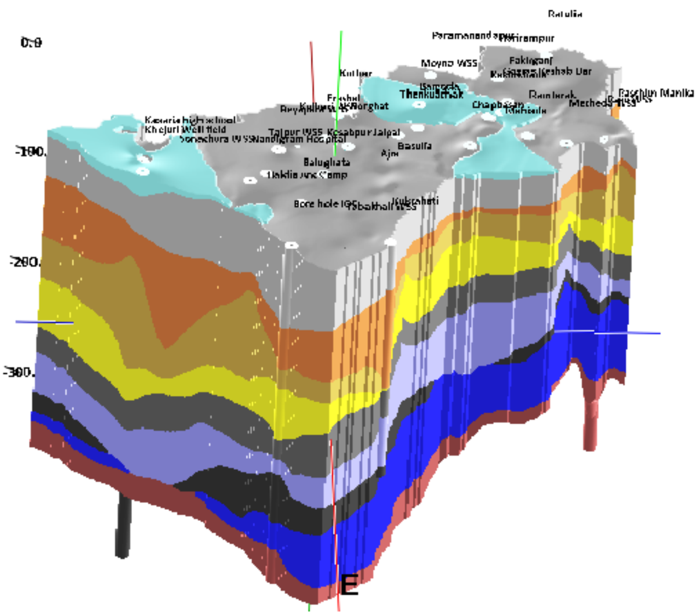
REPORT ON

AQUIFER MAPPING STUDIES AND MANAGEMENT PLAN IN PARTS OF PURBA MEDINIPUR, WEST BENGAL



CENTRAL GROUNDWATER BOARD

Eastern Region, Kolkata

By

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October 2020

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FOREWORD

To understand the nature and occurrences of groundwater, Aquifer geometry, dispositions & characteristics and management of groundwater resource, National Aquifer Mapping & Management Programme (NAQUIM) has been taken up by CGWB under XIIth Plan. During the Annual Action Plan 2017-2018, Aquifer Mapping studies & Management plan was taken up in eastern part of **PURBA MEDINIPUR district**.

Relevant data in respect of the said subjects have been collected from different departments and their publications, viz. Public Health Engineering Dept., State Water Investigation Dept., Agri.-Irrigation Dept., Bureau of economics & Statistics, Land & Land Reforms Dept., Data of Indian Meteorological Dept., National Bureau of Soil Survey & Land Use Planning, etc. of Govt. of India have also been used. Hydro-geological data is sourced from the scientific studies of CGWB pertaining to groundwater explorations, hydrogeological surveys, chemical analysis and outsourcing explorations being taken up for data generation.

Compilation of this report, evaluation of data and preparation of relevant maps, 2D cross-sections & 3D models of aquifers and their reproduction in the form of present report is outcome of the efforts given by **Sanjib Chakraborty, Scientist-B under the supervision of Dr. S Brahma, Scientist-D & Supervisory Officer (NAQUIM).**

Effective method of dissemination of the existing technical information to different user agencies is an important aspect of NAQUIM which plays a very vital role in the safe and optimal development of groundwater resources in our country. In this regard, Central Ground Water Board has taken up a great initiative in incorporating NAQUIM project since 2012 to fulfil this directive. It is much anticipated that, this report will become an important tool not only for various user agencies, Engineers, Scientists, Administrators, Planners, and others involved in groundwater planning, development and management but also to the common public to make them aware of local groundwater issues and its sustainable management.

(Dr. S. K. Samanta)
Regional Director

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1.0 INTRODUCTION

The State of West Bengal owing to its huge thickness of unconsolidated and semi consolidated sediments is blessed with plenty of ground water resources. Abundant land and water resources, rich fertile soils, intensive agriculture activities and high population density characterise the alluvial parts of the State. Among the major geo-morphological division in West Bengal, parts of Purba Medinipur, Howrah, South 24 Parganas and North 24 Parganas district comprises the deltaic alluvial plain and coastal alluvial plain in the State. Geological set up and paleo-depositional historyof the area controlled the occurrence and distribution of the sediments, so thus, the aquifersdispositions in the area. The multi-layered aquifer systems with wide lateral facies variation are very much significant in the area. The fluviatile sediments forming the freshwater aquifers deposited by the ancient river systems has been subjected to multiple marine transgression and regression from sea to inlands which resulted in erosion, redistribution and re-deposition of sediments, thus, creating complex, continuous or discontinuous disposition of aquifers widely varying in hydraulic characters and water quality. The National Aquifer Mapping and Management Programme (NAQUIM) of Central Ground Water Board (CGWB) has been envisaged to focus on the aquifer geometry, occurrences, availability of ground water resources and quality and to formulate management plan of the individual aquifer system for the sustainable development.

Under the Annual Action Plan of 2017-18 of CGWB, ER, NAQUIM studies were undertaken in Purba Medinipur district, West Bengal. The present study includes parts of the Purba Medinipur district comprising a mapable area of 1820 sq km. in 13 blocks in Tamluk, Haldia and in parts of Contai Subdivision.

1.1 Objective

The broad objective of the study is to establish the geometry of the underlying aquifer systems in horizontal and vertical domain, its resources potential in respect of quantity and quality, aquifer characterization, scope for development potential and prepare aquifer-wise management plan for drinking and domestic sectors and for agriculture activities.

1.2 Scope of Study

The scope of the present study is broadly within the framework of National Aquifer Mapping & Management Programme (NAQUIM) being implemented by CGWB. There are four major activity components viz.: (i) Data collection / compilation (ii) Data gap analysis (iii) Data generation and (VI) Preparation of aquifer maps and management plan to achieve the primary Objective. Data compilation includes collection, and wherever required procurement, of all maps and data from concerned agencies, such as the Survey of India, Geological Survey of India, State Governments etc., computerization and analyses of all acquired data, and preparation of a knowledge base. Collection and compilation of litholog, wells assembly, electrical log reports and yield test data of the tube wells of PHED, Govt. of west Bengal and Agri Irrigation Department of Govt. of West Bengal plays an important role in accomplishing the work. Identification of Data Gap includes ascertaining requirement for further data generation (hydro-geological, geophysical, chemical, hydrological, hydro-meteorological etc.) in addition to the existing data in respect of prevailing hydrogeological subsurface geological condition in the area. Data generation includes pre and post monsoon monitoring of aquifer wise water level from the existing network monitoring wells and other available feasible wells, spot measurements of electrical conductivity of the water samples from the wells, incorporation of observation based on field studies, data collection through ground water exploration work in the study area, collection of water samples etc.

1.3 Approach and Methodology

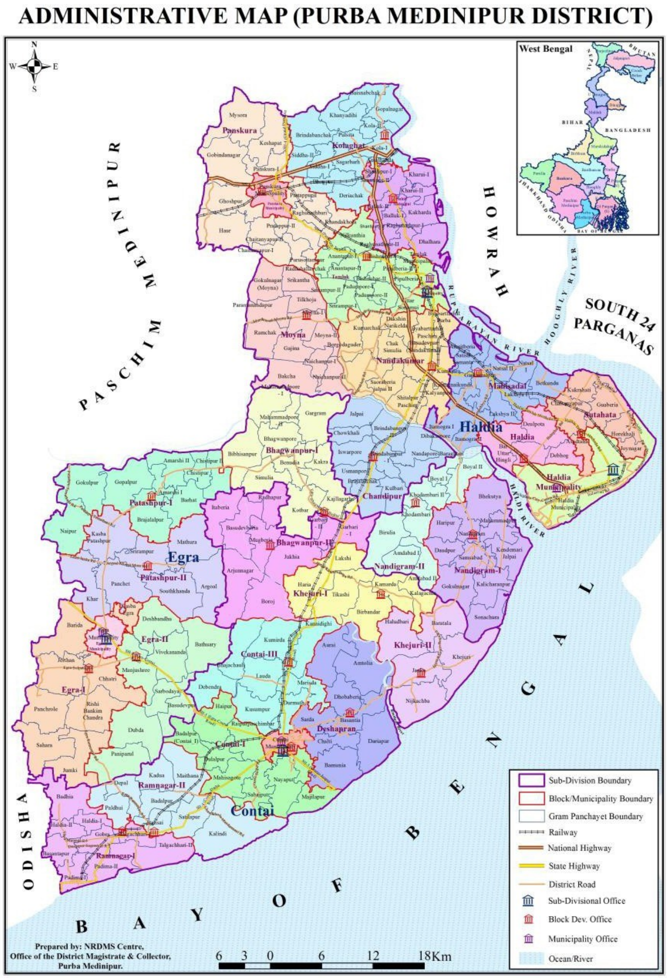
An approach and methodology adopted to achieve the major objective have been shownbelow step-wise.

- Compilation of existing data and reports of CGWB
- Identification of data gaps
- Data generation through monitoring of pre and post monsoon water level from the NHNS stations and key observation wells in different aquifers, monitoring of water quality, spot measurement of conductivity, exploratory drilling for study of subsurface geology, preparation of lithological logs, yield and aquifer parameter data through construction of tube wells.
- Collection, compilation and analysis of lithologs, electrical logs and yield data of the water supply wells of PHED, Govt of West Bengal and Agri Irrigation Department, Govt. of West Bengal
- Preparation of thematic maps on GIS platform
- Identification/demarcation of individual aquifer systems in the area from the available lithologs, electrical logs, previous literature, and observation from field studies etc.
- Preparation of 2D/3D aquifer disposition maps in Rockworks Platform
- Analysis of 2D and 3D maps, assessment of existing draft and resource of individual aquifer systems.

Considering the demand and supply status in drinking, domestic, industrial and agriculture sectors the suitable management plan has been designed. The scope for rainwater harvesting for artificial recharge or conservation is reviewed and accordingly suitable structures are recommended.

1.4 Location, Extent and Accessibility of the study area

The study area is in the lower deltaic and coastal region in parts of Purba Medinipur district in West Bengal in the southern parts of the State. The area covers a mappable area of 1820 sq. km in 13 blocks in Tamluk, Haldia and in parts of Contai subdivision of Purba Medinipur district. The study area extends between 88°12’40”E to 87°38’15”E longitude and 21°43’30” N to 22°31’15” N latitude. The area falls in Survey of India toposheets no 73N/11, 73N/12, 73N/15, 73N/16,73O/13, 79B/4. It is bounded in the south and southeast by Bay of Bengal, in the east by the Rupnarayan River, Howrah and Paschim Medinipur district in the north and Paschim Medinipur district and Bhagawanpur and Contai blocks of Purba Medinipur district in the West. Among the 13 blocks in the study area Kolaghat, Panskura, Moyna and parts of Sahid Matangini and Tamluk, are inland blocks and rest 8 blocks, namely Mahisadal, Nandakumar, Haldia, Sutahata, Chandipur, Nandigram I and II and Khejuri II blocks are coastal blocks.



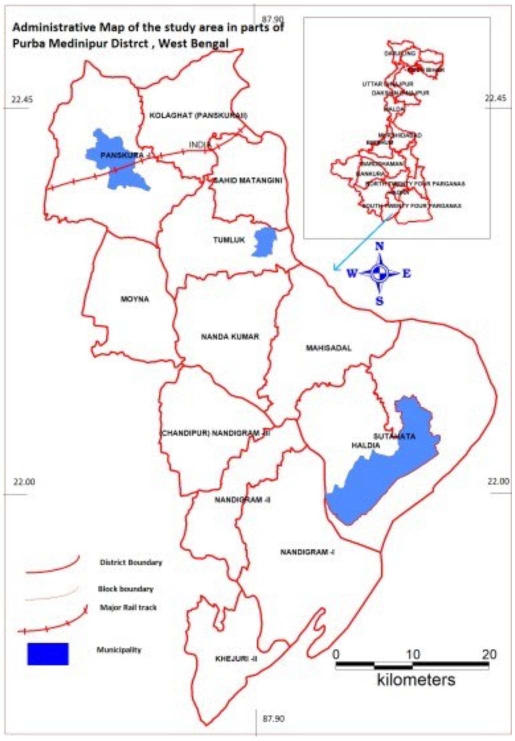


Table 1.1 Administrative Map of the study area

Table 1.2 Administrative map of the Study area showing Block Boundaries and Municipalities

The coastal blocks and the inland blocks are generally demarcated on the basis of saline water penetration in drainage and canal networks in the area. Ingress of sea water through Rupnarayan, Haldi and Rasulpur river has been witnessed with minor influence of tributaries of these rivers. The district head quarter is at Tamluk and is well connected through road and rail network with the State capital Kolkata.

1.5 Administrative divisions and Demographic Details

The study area comprises two subdivisions and parts of one subdivision, 7 blocks in Tamluk subdivision, 5 blocks in Haldia subdivision and 1 block in Contai subdivision.

Table 1.3 Major Administrative Division

Subdivisions	Blocks
Tamluk	Kolaghat
	Panskura
	Sahid Matangini
	Tamluk
	Moyna
	Chandipur

	Nandakumar
Haldia	Haldia
	Sutahata
	Mahisadal
	Nandigram I
	Nandigram II
Contai	Khejuri II

The area covers total 126 Gram Panchayet, 1212 inhabited villages, 15 census towns, 2766 habitations and 562227 households. Urban cluster in the study area mainly concentrated around 3 Municipalities Haldia, Tamluk and Panskura.

Table 1.4 Major Administrative Division

Block Name	Inhabited Villages	Census Town	Panchayet	Habitation	HH
Chandipur	111	2	10	185	40,168
Haldia	24	0	4	91	22,385
Khejuri - II	95	0	5	245	27,260
Kolaghat	105	4	13	230	62,519
Mahisadal	73	1	11	158	44,970
Moyna	85	1	11	359	53,356
Nanda Kumar	100	0	12	210	59,240
Nandigram - I	98	1	10	203	42,289
Nandigram - II	39	1	7	154	26,902
Panskura	225	0	15	288	62,854
Sahid Matangini	81	2	10	262	45,038

Sutahata	78	1	6	176	26,936
Tamluk	98	2	12	205	48,310
Total	1212	15	126	2766	562227

Table 1.5 Population Detail in the Study Area

Sub-Division / C.D.Block / M	Total Workers (TW)	Class of Total Workers						Non-workers	Total Population
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Tamluk	106904	100160	207064	5554	5158	10712	112458	105318	217776
Sahid Matangini	95352	88635	183987	7792	7431	15223	103144	96066	199210
Panskura-I	145563	137740	283303	-	-	-	145563	137740	283303
Kolaghat	124283	115363	239646	25963	24515	50478	150246	139878	290124
Moyna	114551	105779	220330	3438	3159	6597	117989	108938	226927
Nandakumar	135720	127278	262998	-	-	-	135720	127278	262998
Chandipur	91342	85362	176704	5781	5634	11415	97123	90996	188119
Tamluk(M)	-	-	-	33260	32046	65306	33260	32046	65306
Panskura(M)	-	-	-	29740	28192	57932	29740	28192	57932
Mahishadal	103023	96590	199613	3368	3296	6664	106391	99886	206277
Nandigram-I	103880	98152	202032	2947	2856	5803	106827	101008	207835
Nandigram-II	60601	57344	117945	2722	2552	5274	63323	59896	123219
Sutahata	60892	57737	118629	2617	2538	5155	63509	60275	123784
Haldia	50531	47461	97992	-	-	-	50531	47461	97992
Haldia(M)	-	-	-	104841	95986	200827	104841	95986	200827
Khejuri-II	71294	68169	139463	-	-	-	71294	68169	139463
Total	1263936	1185770	2449706	228023	213363	441386	1491959	1399133	2891092

	Number	P.C.	Cultivators		Agricultural Labourers		Agriculture Worker	Household Ind. Workers		Other Workers		Number	P.C.	
			Number	PC to TW	Number	PC to TW	Number	Number	PC to TW	Number	PC to TW			
(1)	(2)	(3)	(4)	(5)	(6)	(7)		(8)	(9)	(10)	(11)	(16)	(17)	(18)
Tamluk	88053	40.43	15771	17.91	31401	35.66	47172	8201	9.31	32680	37.11	129723	59.57	217776
Sahid Matangini	72746	36.52	8884	12.21	18565	25.52	27449	6304	8.67	38993	53.60	126464	63.48	199210
Panskura-I	130131	45.93	30980	23.81	46520	35.75	77500	12662	9.73	39969	30.71	153172	54.07	283303
Kolaghat	108809	37.50	15545	14.29	21973	20.19	37518	13935	12.81	57356	52.71	181315	62.50	290124
Moyna	86813	38.26	17464	20.12	41363	47.65	58827	2740	3.16	25246	29.08	140114	61.74	226927
Nandakumar	103599	39.39	19136	18.47	35377	34.15	54513	12350	11.92	36736	35.46	159399	60.61	262998
Chandipur	67904	36.10	9140	13.46	27771	40.90	36911	7189	10.59	23804	35.06	120215	63.90	188119
Panskura(M)	19822	34.22	1499	7.56	2779	14.02	4278	1239	6.25	14305	72.17	38110	65.78	57932
Tamluk(M)	22929	35.11	448	1.95	698	3.04	1146	522	2.28	21261	92.73	42377	64.89	65306
Mahishadal	74017	35.88	8342	11.27	25674	34.69	34016	3733	5.04	36268	49.00	132260	64.12	206277
Nandigram-I	66239	31.87	9883	14.92	29072	43.89	38955	2978	4.50	24306	36.69	141596	68.13	207835
Nandigram-II	43002	34.90	7806	18.15	21641	50.33	29447	1041	2.42	12514	29.10	80217	65.10	123219
Sutahata	40143	32.43	3294	8.21	16364	40.76	19658	1183	2.95	19302	48.08	83641	67.57	123784
Haldia	35776	36.51	5490	15.35	13076	36.55	18566	1008	2.82	16202	45.29	62216	63.49	97992
Haldia(M)	61216	30.48	2316	3.78	5176	8.46	7492	1331	2.17	52393	85.59	139611	69.52	200827
Khejuri-II	47186	33.83	9268	19.64	17854	37.84	27122	1527	3.24	18537	39.28	92277	66.17	139463
TOTAL	1068385		165266		355304		520570	77943		469872		1822707		2891092

Table 1.6 Distribution of Population over different Categories of Worker and Non-Workers

Source: District Statistical Handbook, 2014 & PHED, Govt. of WB

The area is principally rural area, among the total population of 2891092, 15% is the urban population restricted in 3 municipalities and 15 census towns and rest 85% comprises rural population.

Classification of the population on the basis of workers and non- workers shows that only 37% of the total population is the working mass for the area and rest 63% are non-workers. Among the workers cultivators and agriculture labours together constitutes the agriculture workers which is only 18% of the total population. 3% constitute the households and industrial workers and 16% other workers. Therefore, the persons engaged in the agriculture as wells as in the industrial sectors in the area is less.

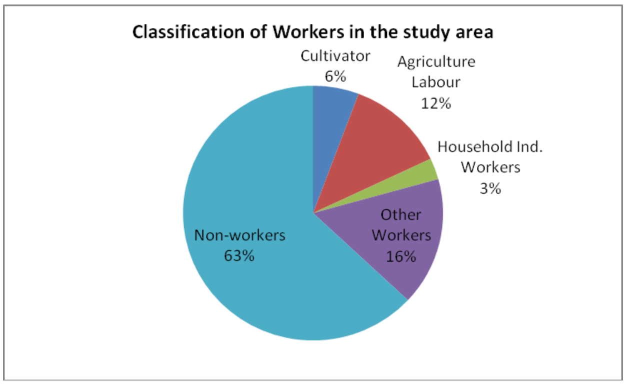


Table 1.7 Classification of workers in the study area

1.6 Landuse, Irrigation and Cropping pattern

The geographical and cultural features of Purba Medinipur District determine the suitability of its land for agricultural activities. Apart from land, water availability is another important factor influencing cropping pattern and production in the study area. The dynamic geomorphic nature in the coastal parts also influences the land use patter. Land cover is dynamic both spatially and temporally. Similarly, factors influencing land use pattern are variable as well. The nature of the underlying soils, rainfall pattern, human factors, classes of worker etc to some extent influence the land use pattern in the area. The rapid growth of population, urbanization, industrial development around Haldia, Panskura, Tamluk urban clusters leads to the squeezing of agriculture lands and results in increase in area of non-agriculture activities. On the other hands, due to extension of irrigation facilities in the new area and introduction of modern techniques of irrigation and agriculture has influenced to bring more area under plough. Therefore, net sown area and the area sown more than once has also increased in the area as compared to the historical data. More area has been brought under boro cultivation. The proper utilisation of lands, particularly in the coastal tracts may further increase the agriculture lands by increasing the cultivation of cash crops like betel vine, cashew nuts etc.

The forest covers is negligible, is about 0.12% of the total area. The coastal parts of Khejuri II and Haldia blocks have few forests cover. Area under non agriculture uses includes settlement area etc and constitutes 32% of the total area. The major parts of the study area are suitable for agriculture activities and 68% area is cultivable area.

PURBA MEDINIPUR DISTRICT
(LANDUSE & LANDCOVER MAP)

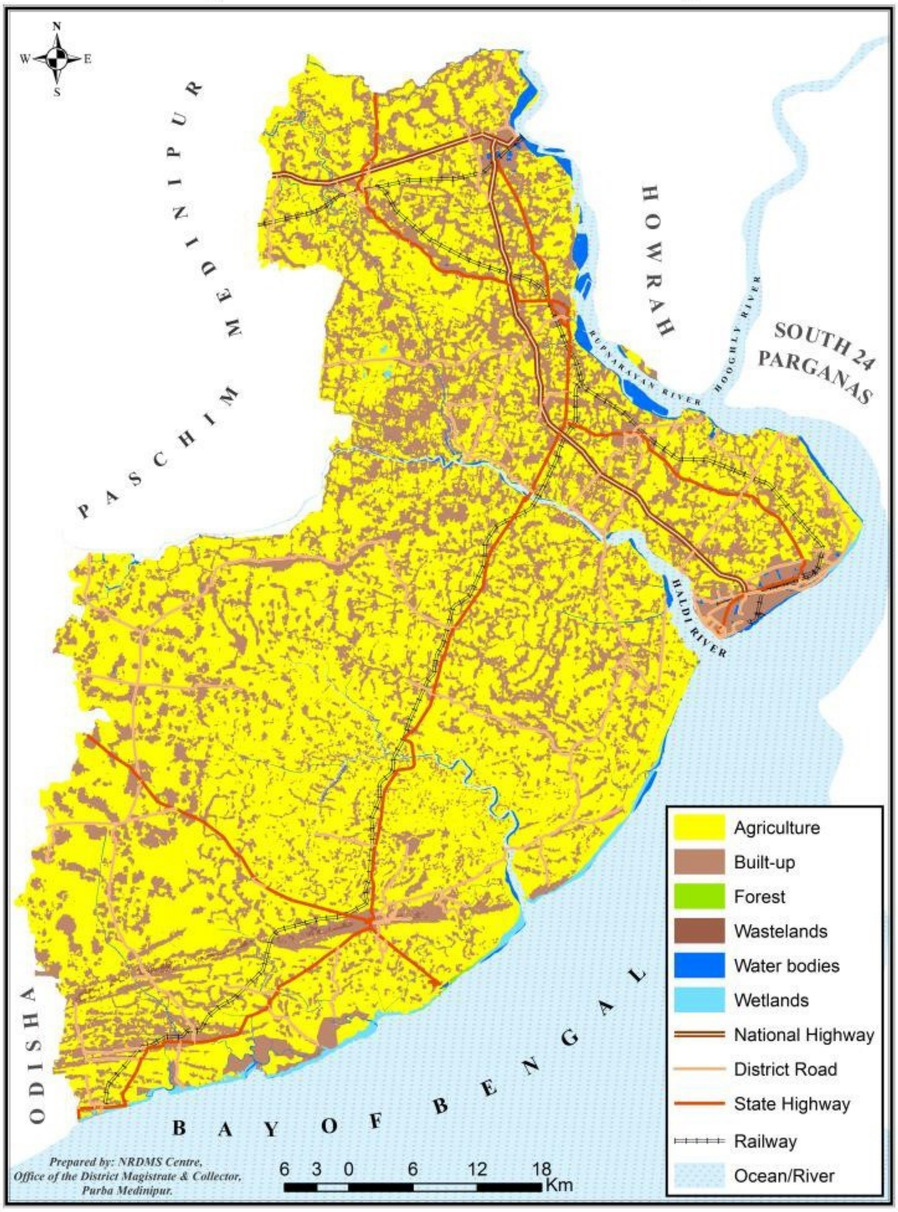
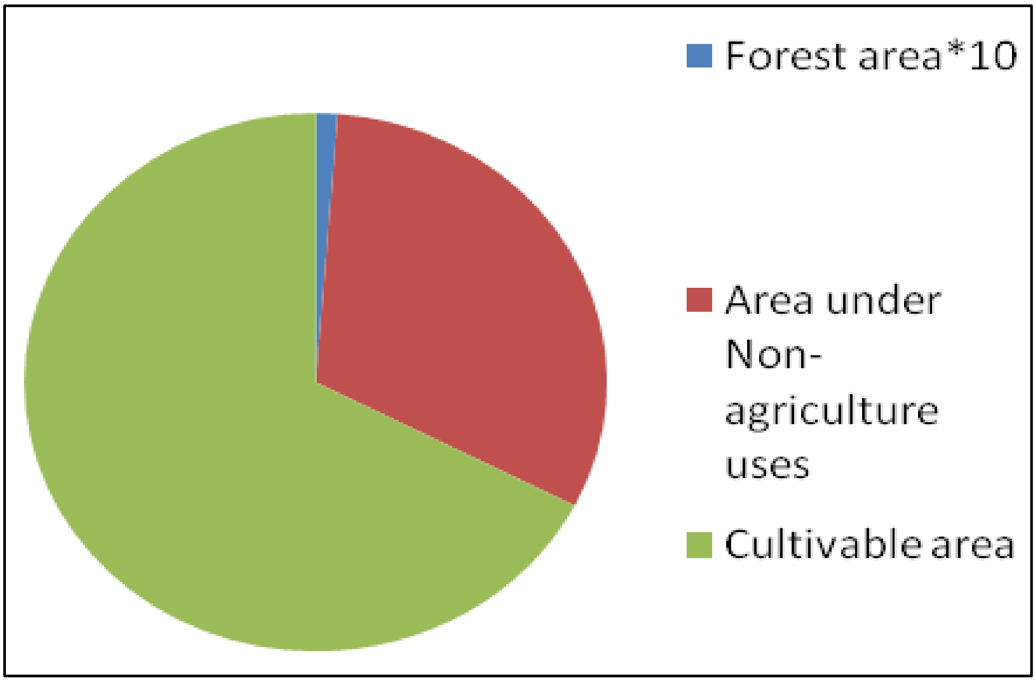


Table 1.8 Landuse & Landcover Map

Table 1.9 Block-wise details of Land-use pattern

Name ofthe block	Reporting area	Forest area	Area under non-agriculture wastes	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Barren and un-culturable lands	Net area sown
Kolaghat	15046	0	4106		93	6		74		10767
Panskura	24679	0	7201		95			407		16976
Sahid Matangini	9570	0	2724		94					6752
Tamluk	13291	0	5928	5	40	1				7317
Moyna	14712	0	3649		46		1			11016
Nandakumar	16469	0	4349		54					12066
Chandipur	13586	0	3156		96					10334
Haldia	11379	161	6332	1	49					4836
Sutahata	16627	0	10815	2	58					5762
Mahisadal	14525	0	4450		93			50	7	
Nandigra m I	17283	0	3624		104				7	
Nandigra m II	10721	0	1675		25					
Khejuri II	13619	71	2718							



(Source- West Bengal Land use Land cover Department)

Table 1.10 Area under coverage of major land utilization in the study area

1.7 Irrigation

Irrigation plays an important role for crop production and intensity of crops. Among

68% of the cultivable lands in the study area 45-50% is rain fed irrigation (as revealed by the kharif /aman crops grown statistics) and in the rest area crop production is solely dependent of surface water and ground water irrigation systems. 42% area has been brought under ground water irrigation. Ground water irrigation is achieved by shallow and deep tube wells; however, recently medium duty tube wells are also considered for irrigation uses. Irrigation by surface water is done through canals, surface flow and lift irrigation, and from tanks. Ground water irrigation is mainly prevalent in the inland blocks of the study area. Coastal blocks or the blocks adjacent to the coastal blocks like Haldia, Sutahata, Nandigram I and Nandigram II, Mahisadal, Nandakumar do not hold significant number of irrigation tube wells. 70-75% irrigation tube wells lie within the depth range of 0-100 m in inland blocks whereas in the coastal blocks 80% -90% wells are within 100-300 mbgl. Table 1.11 explains that the total culturable command area created so far by ground water and surface water irrigation schemes. 37% of the total area is brought under culturable command area in study area among which 15.5% of total area by ground water-based schemes and 21% by surface water schemes.

Table 1.11 Area irrigated by different sources in the study area (ha)

Name of Block	Canal Area	Tank		DTW		STW		RLI		Others	
		No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(14)	(15)
Tamluk	-	1850	500	42	700	4	16	3	100	..	6200
Sahid Matangini	-	6890	695	-	-	-	-	3	120	..	4500
Panskura-I	777	1529	1161	897	8697	174	696	21	780	..	-
Kolaghat	460	4050	1400	168	1130	2	110	16	720	..	5437
Moyna	0	2855	1235	255	3650	217	1303	5	75	..	5730
Nandakumar	300	30555	1350	7	105	69	610	16	410	..	5060
Chandipur	130	18815	2350	262	2910	-	-	-	-	..	-
Mahishadal	-	948	500	3	*	11	55	20	375	..	6130
Nandigram-I	-	18225	2865	-	-	-	-	-	-	..	121
Nandigram-II	-	6565	735	-	-	130	1500	-	-	..	600
Sutahata	-	110	200	-	-	-	-	11	*	..	3300
Haldia	1378	560	710	1	25	-	-	22	250	..	-
Khejuri-II	60	14155	3265	57	1360	4	18	-	-	..	25

District Statistical Hand book (2013-14)

Table 1.12 . Culturable Command Area Created by Surface and Ground Water

Sl. No.	Block Name	Dug well	Sallow Tube well	Medium Tube well	Deep Tube well	Surface Flow	Surface Lift	CCA (ha.)		Total CCA (ha.)
		CCA (ha.)	CCA (ha.)	CCA (ha.)	CCA (ha.)	CCA (ha.)	CCA (ha.)	Ground Water	Surface Water	
1	CHANDIPUR	2.20	4692.27	141.70	1.00	75.30	7187.20	4837.17	7262.50	12099.67
2	HALDIA	0.00	170.00	0.00	0.00	104.15	2405.35	170.00	2509.50	2679.50
3	KHEJURI - II	6.69	600.63	541.45	0.00	242.36	402.28	1148.77	644.64	1793.41
4	KOLAGHAT	97.24	1570.35	20.00	1688.71	1178.53	2318.56	3376.30	3497.09	6873.39
5	MAHISHADAL	25.00	1429.62	2.00	243.00	2369.56	2983.06	1699.62	5352.62	7052.24
6	MOYNA	543.30	1568.94	20.00	172.58	1072.28	465.72	2304.82	1538.00	3842.82
7	NANDAKUMAR	0.00	434.22	0.00	160.00	565.97	3126.76	594.22	3692.73	4286.95
8	NANDIGRAM -I	0.90	3.00	42.56	0.00	156.01	5515.80	46.46	5671.81	5718.27
9	NANDIGRAM -II	10.00	163.15	975.86	0.00	0.00	153.30	1149.01	153.30	1302.31
10	PANSKURA - I	32.81	2349.77	3418.70	6188.69	208.05	1035.90	11989.97	1243.95	13233.92
11	SAHID MATANGINI	10.00	44.90	0.00	141.00	85.01	1606.94	195.90	1691.95	1887.85
12	SUTAHATA	0.00	0.00	0.00	0.00	2043.32	1217.78	0.00	3261.10	3261.10
13	TAMLUK	19.00	167.32	71.00	359.20	118.18	2015.38	616.52	2133.56	2750.08
	TOTAL:-	747.14	13194.17	5233.27	8954.18	8218.72	30434.03	28128.76	38652.75	66781.51

Source: 5th MI census data

1.8 Crops grown and cropping pattern:

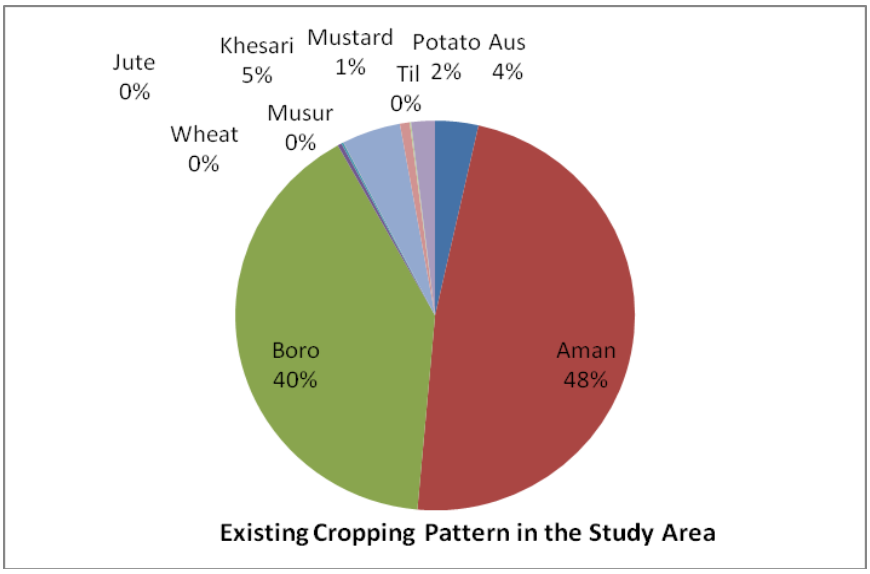
Agriculture is one of the principal sources of livelihoods of the people in the area. Cultivator and agriculture labour constitute about 60% of the workers. The major crop in the area includes paddy followed by pulses, potato, mustard and little wheat and jute. Besides that, in favourable location few rabi vegetables, floriculture and horticulture crops are grown. The aman paddy, the principal paddy production is rainfed whereas boro paddy which is solely dependent on irrigation water, is also grown in considerable amount. The less draining capacity of impermeable soils in major parts of the area impedes cultivation of significant wheat, potato or pulses etc. The less production of pulses, oilseeds etc is a concern for future in the district. Therefore, diversification of cropping pattern is urgently needed in the area.

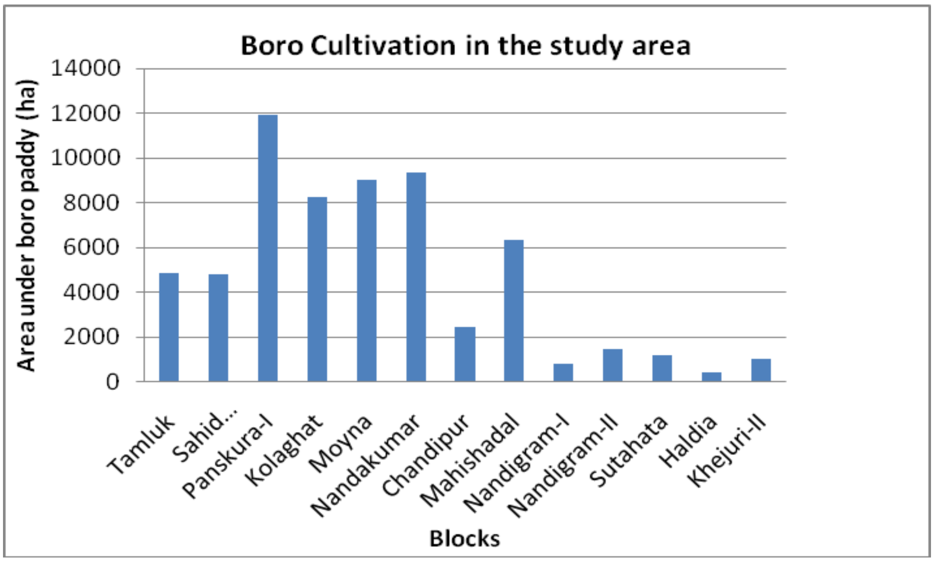
The hydrogeomorphic features in the coastal region restrict double /multi-cropped area, due to less availability of fresh irrigation water either from ground or surface water sources. The canals, bills etc become brackish in nature in summer season due to tidal influences. The coastal blocks like Haldia, Sutahata, Nandigram I, II, Khejuri etc. is mainly mono cropped. Cultivation of summer /boro paddy is very less in the coastal tracts. However, now a days cultivation of cash crops and other profitable floriculture/horticulture crops are being cultivated in few pockets in favourable locations. Cashewnuts, pan baroj along the coastal tracts and marigolds, tuberose, betel vine in the inland's blocks are being encouraged. Thus, diversification of cropping pattern and shifting to alternative crops will ultimately aids to increase the effective cropping intensity of the area.

Table 1.13 Area of Major Crops in the Study Area (ha)

Name of Block	Aus		Aman		Boro		Wheat		Jute		Musur		Mustard		Potato	
	Area	Yield	Area	Yield	Area	Yield	Area	Yield	Area	Yield**	Area	Yield	Area	Yield	Area	Yield
Tamluk	4	669	1432	625	4885	3662	504	2624	58	13.54	-	-	5	1091	1	15338
Sahid Matangini	-	-	2385	787	4826	3590	5	2624	-	-	1	1066	2	1091	102	32974
Panskura-I	621	723	2614	57	11926	3325	-	-	-	-	30	1295	921	1077	1313	39463
Kolaghat	-	-	3186	843	8249	3645	-	-	-	-	-	-	31	594	2	23381
Moyna	-	-	2148	825	8997	3460	-	-	186	13.54	-	-	57	1091	265	32949
Nandakumar	-	-	2441	617	9327	3507	-	-			-	-	-	-	72	29522
Chandipur	1243	477	2248	344	2462	3527	-	-	2	13.54	-	-	23	605	121	27716
Mahishadal	150	2044	9894	1281	6356	3753	-	-	-	-	-	-	4	575	19	27285
Nandigram-I	3187	2044	23845	1867	810	3789	-	-	3	13.54	-	-	57	575	429	16804
Nandigram-II	143	2044	8527	1343	1470	3708	-	-	-	-	-	-	50	616	230	17878
Sutahata	-	-	4596	1263	1206	3226	-	-	-	-	-	-	-	-	14	27251
Haldia	-	-	1571	448	432	3169	-	-	-	-	-	-	-	-	-	-
Khejuri-II	-	-	8478	1297	1020	3349	-	-	-		-	-	67	685	374	28000

Table 1.14 Boro cultivation with cropping pattern distribution





1.9 Urban areas, Industries and Mining activities

Urban areas in the study area include 3 municipalities, Tamluk, Panskura and Haldia. Besidesthat, 15 census towns also holds urban agglomeration.

The mining activities are insignificant in the area. The Haldia Industrial belts in the southern part of the area is the principal and well-known industrial area. Haldia Petrochemicals, Indian oil refineries, Tata chemicals, Mitsubishi etc. in Haldia Industrial area and Kolaghat Thermal power plants in Kolaghat block is the principal industries in the area. Besides, few medium and small-scale industries like cashew nut processing units etc are worth mentioning.

2.0 CLIMATE

The climate of the area is characterized by hot and humid climate with adequate rainfall mainly derived from south-west monsoon, which starts from mid-June and continue up to September. Generally, 85 percent of the rainfall is received during the monsoon period. Pre-monsoon showers are occasionally received in the month of March, April and May.

2.1 Rainfall

The study area receives copious rainfall. Total annual rainfall distribution from 2010-2014 shows that the total annual rainfall varies between 1244 mm to 2078 mm. The monthly distribution of rainfall shows that increase in rainfall from April onwards and higher rainfall from July to September. The data indicates that the year 2010 was rainfall deficient or draught year and the year 2013 was surplus year. The trend of rainfall in the recent years shows normal trend with slightly increasing trend with correlation coefficient of 0.51.

Table 2.1 Distribution of Rainfall

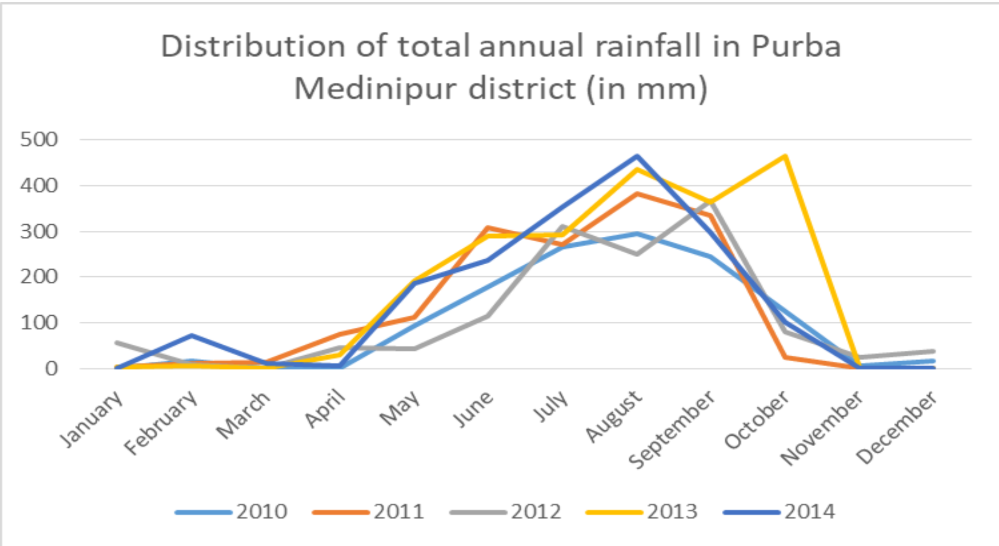
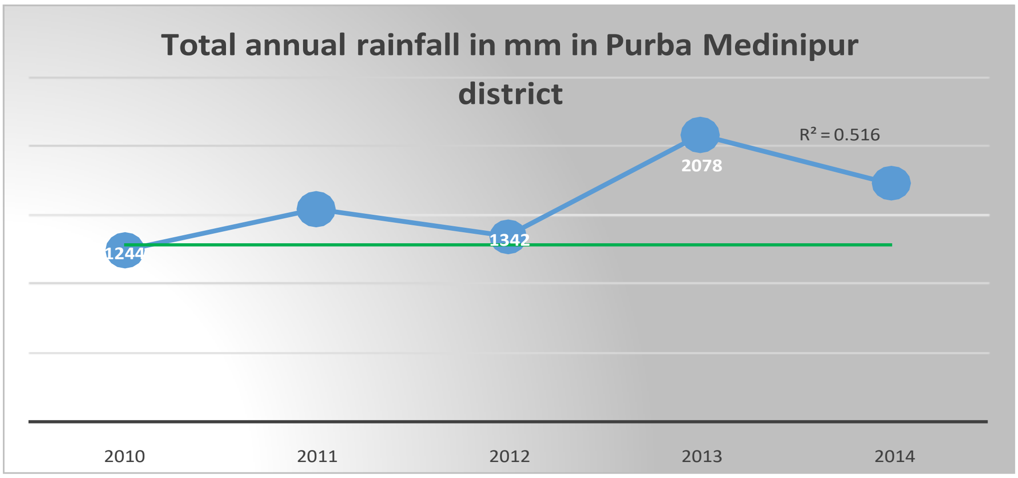


Table 2.2 Total Annual rainfall



The average annual or total normal annual rain fall in Purba Medinipur district is 1663.3 mm which is above than that of normal annual rainfall of 1502 mm in the Gangetic West Bengal. However, the state average normal annual rainfall is about 1829.2 mm. The annual distribution of rainfall pattern in Purba Medinipur district revels that the rainfall starts from the mid of April and end July to September receives the maximum rainfall.

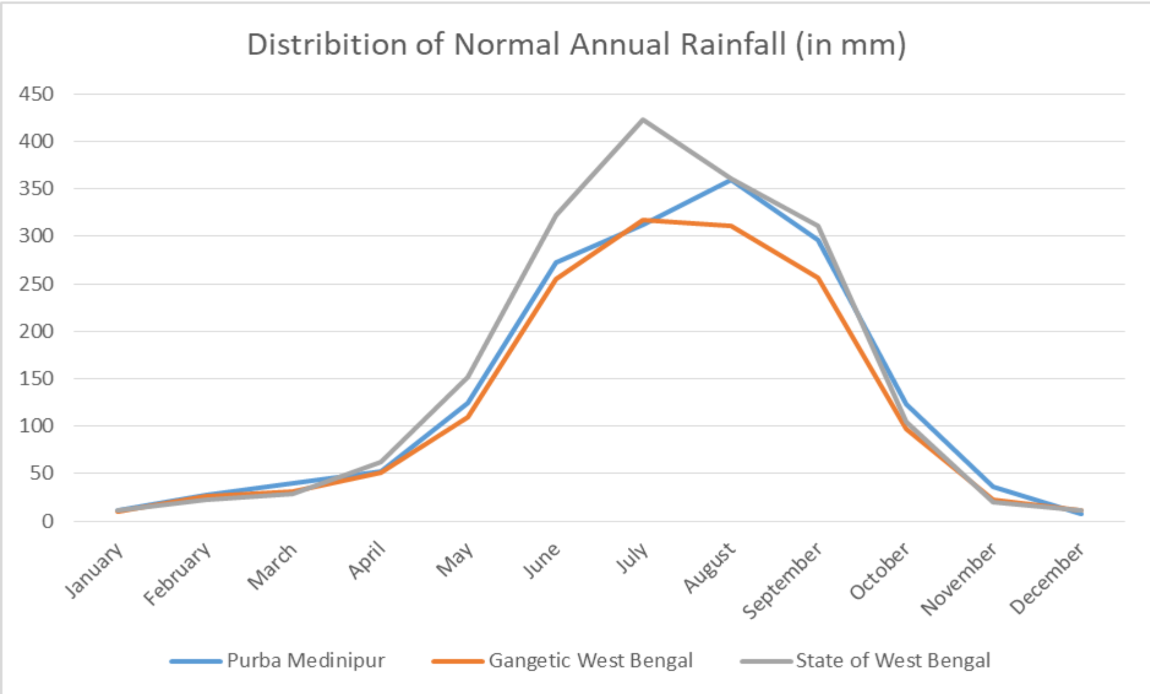


Table 2.3 Distribution of Normal Rainfall

2.2 Temperature

In the coastal part of the district temperature varies from mean minimum of 22°C to mean maximum of 34°C annually. The humidity level is about 85% on the average. The Southwest and Southern part of Medinipur is prone to tidal waves and cyclones.

The winter season sets in around middle of November when both maximum and minimum temperature begin to drop steadily and attain their respective lowest values in the month of January. The temperature starts rising in the month of February. May-June is the hottest month of the year.

3.0 PHYSIOGRAPHY

3.1 Geomorphology

Purba Medinipur district is part of the lower Indo-Gangetic Plain and Eastern coastal plains. Topographically, the district can be divided into two parts: (a) almost entirely flat plains on the west, east and north; and (b) the coastal plains on the south. The parts of the study area fall in flat alluvialterrain and the area in the south and south east is in the coastal plain. The district is characterised by gently sloping flat alluvial terrain, which gradually merges towards coastal plain further south. The elevation of land mass ranges from 10 -12 m above mean sea level in the northern part to 3 to 4m above mean sea-level at the coast. After that the land gradually dips into the Bay of Bengal. In the vicinity of coast in Khejuri II block, a series of sand dunes stretching East-North-East to West-South- West direction are present, from coast towards inlands which is indicative of gradual shifting of shorelines.

3.2 Drainage

The drainage system of the area is controlled by the Rupnarayan, Haldi and Rasulpur river flowing in southeast direction along the northern and eastern fringe, through the central parts and along the southern boundary of the study area. The Drainage Map of the study area is shown in

Table 3.2

Table 3.1 River and Catchment

Sl no	Name of River	Catchment area in sq km	Length of river in the district in km.
1	Rupnarayan	1226	80
2	Haldi	614	42
3	Rasulpur	1556	19

Rupnarayan:

The River is formed from the confluence of Shilabati and Dwarkeshwar at Bandar near Ghatal town of Paschim Medinipur district. After receiving contributions from other minor tributaries, the Dwarakeswar finally joins with Shilabati to form the river Rupnarayan. The Kana Dwarkeshwar, Polashpai, Durbachaty are the tributaries of the Rupnarayan. The Rupnarayanriver is the main tributary of the Hooghly and receives tidal flow from Bay of Bengal, as well as flow from the major tributaries of Dwarkeshwar, Shilabati, Kangsabati, and Mundeshwar. It also receives flow from a number of drainage channels, like Kata Khal, Bakshi Khal, and Chandreshwar Khal of Paschim Medinipur.

Haldi: The River Haldi is formed by joining of New Cossye and Kaliaghai and after traversing south- eastwards outfalls into the river Hooghly near Haldia town. The river divides Purba Medinipur district into two parts; the northern part can be categorized as drainage area of Tamluk and the southern part can be categorized as Rasulpur-Nandigram drainage area. The lower portion of the river Haldi is affected by over bank spills and drainage problem during the monsoon as entire stretch of 42 km of the river falls under the tidal influence of river Hooghly. Haldi River has maximum influence on the drainage controls of the study area and the tidal effect in the river affects the local hydrogeomorphic setup and environment of the area, too.

Rasulpur: The River Rasulpur flows through the Paschim Medinipur and Purba Medinipur district. The river is formed by three streams namely Bagda, Sarpai and Madhakhali. It is the main drainage channel in Contai Sub-Division of Purba Medinipur district. The river marks the southern boundary of Khejuri II blocks of the study area and ultimately outfalls into the river Hooghly at the mouth of Bay of Bengal. The length of this river is 19 km.

The drainage networks in the study area, although comprises coastal tracts of West Bengal but is entirely different from that of coastal deltaic parts of Sundarban area in south 24 pargana district. The Sundarban delta is dominated by numbers of distributaries of River Ganga whereas the drainage in Purba Medinipur district is controlled by main drainage channels and their tributaries. The tidal influence from Bay of Bengal in Purba Medinipur district is through some restricted channels only.

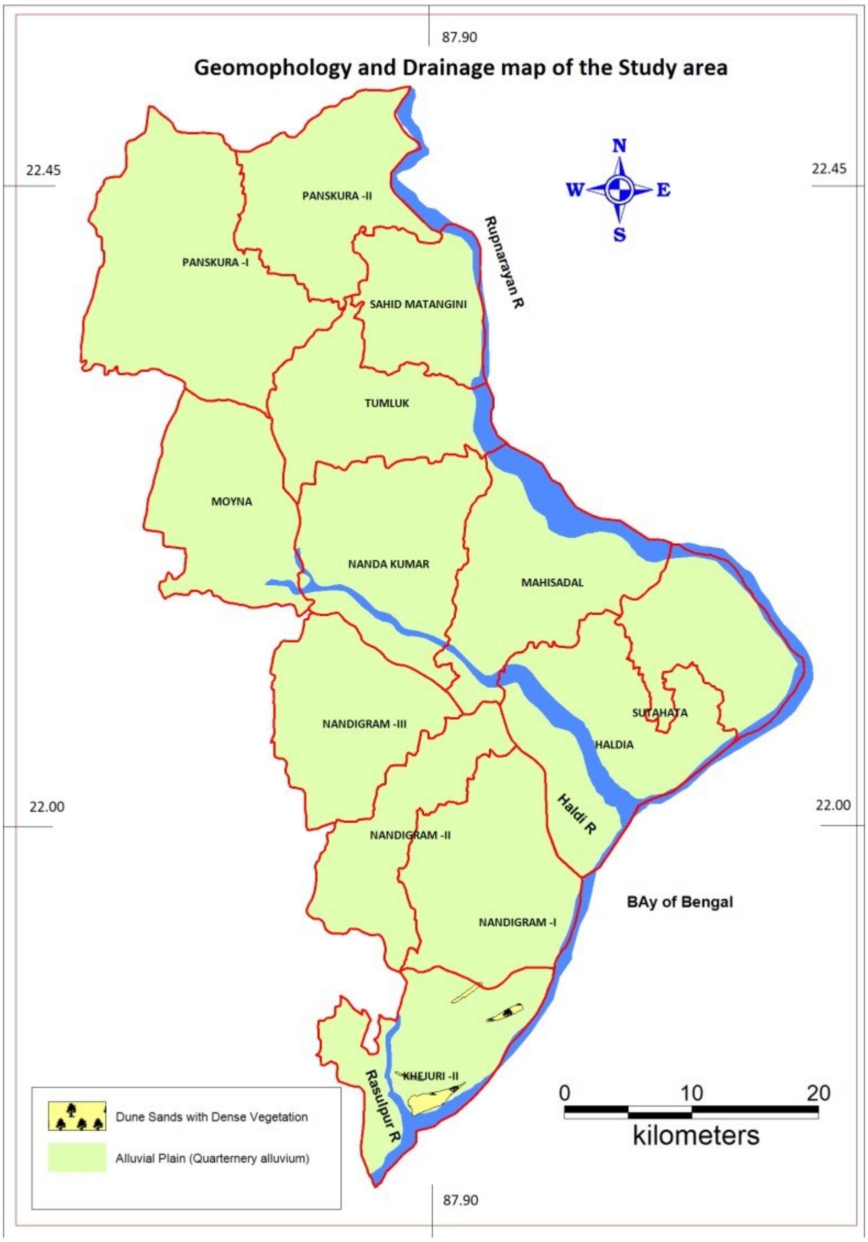


Table 3.2 Geomorphology map of the study area

3.3 Soil Characteristics

The study area is dominated by younger alluvial soils, whereas the older alluvial soils are only found in few patches in parts of Panskura and Kolaghat blocks. Coastal alluvial soils are predominant in the southeastern parts of the area. Saline or saline alkaline soils occupy restricted belts in Purba Medinipur district. The soils are often rich in sodium, magnesium, calcium. On the basis of morphological features, texture, physico-chemical characters the soils are classified dominantly as Entislos and Aridisols.

On the basis of draining capacity, the soils are classified as deep well drained, moderately drained and imperfectly drained soil and poorly drained soil. It is observed that the deep poorly drained impermeable clayey loam is predominant in the study area. The deep imperfectly drained soils are found in few patches in Panskura, Chandipur and Sutahata blocks. Along the coastal tracts well drained permeable soils are encountered in few linear tracts.

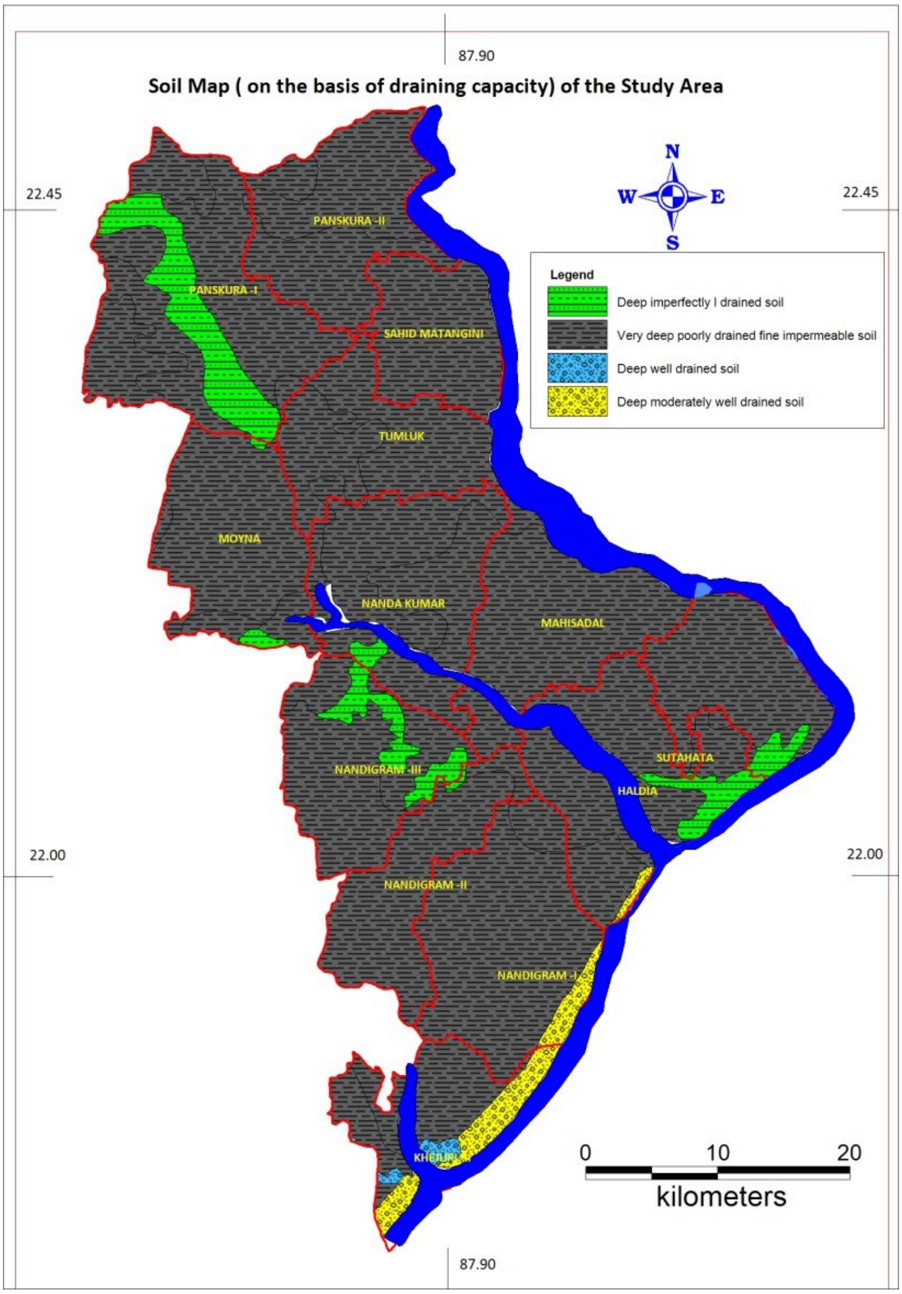


Table 3.3 Soil map of the study area

4.0 GEOLOGY

4.1 General Geology

The study area is underlain by unconsolidated Quaternary alluvium sediments of Holocene and late Pleistocene sediments which is overlain by linear continuous beach ridges (sand dunes) in coastal tracts of Khari II blocks of late Holocene origin.

The thickness of the alluvial sediments increases towards east and southeast following the basin configuration. The Quaternary formation comprises newer alluvium of Recent age and older alluvium of Pleistocene and late Pleistocene age. The older alluvium is exposed in limited patches in Kolaghat blocks and in western parts of Panskura block in Ratulia area. The older alluvium comprises predominantly of yellow to reddish brown clays with kankar and ferruginous gravel and sand fine to medium. The rest of the area is overlain by younger/newer alluvium. The newer alluvium consists predominantly of clay with occasional intercalation of silt and fine sand and is light grey in colour. The Quaternary sediments are underlain by semi-consolidated Tertiary sediments of Mio-Pliocene age. The Tertiary sediments comprises of alternations of graded sand-silt-clay sequence suggesting cyclic sedimentation. In contrast to Quaternaries, the Tertiary are grey in colour with deeper litho- facies being steel grey. The boundary between Quaternary and Tertiary is marked by the occurrences of thick persistent gray clay, which is considered as the "Marker bed" in interpreting and subsequent correlation of subsurface lithology in the area. The area is dominantly of fluvial origin with intermittent effects of marine transgression and regression.

The dune sands in Khejuri area are east to east-southeast continuation of arcuate sand ridges in Contai area. Occurrences of arcuate belts parallel to sub parallel existing coastline are very much conspicuous because of the deep dark vegetation cover. The belt is exactly matches with the inland Contai dunes when extends in the west. The number of small sandy ridges on otherwise silty-clayey tidal flats is the most interesting and important hydrogeomorphic units in the study area. The entire Khejuri village is on the dune itself; other villages on Dune sands in Khejuri II blocks include Poduvery, Kunjapur, Nijkasba etc. The individual sand dunes are separated by low lying agriculture field. The maximum height of this dune varies between 10-15 m. The disposition of dunes of different magnitude from present day coast towards inlands hints for the shifting of the shoreline. The nearly uniform orientation of notch shaped hair pin dunes suggests for uniform wind direction. The sand dunes are characterized by deep vegetation covers.

4.2 Sub Surface Geology

The subsurface geology of the area has been unearthed by correlation of subsurface lithological diagrams, sections and lithological models. The lithologs of the exploratory tube wells of CGWB, selected drinking water supply wells of PHED, Govt of WB and irrigation tube wells of Agri Irrigation department, Govt of WB has been compiled for preparation subsurface correlation diagram. The location of the bore holes which are compiled for lithological disposition has been plotted in the Table 4.1 along with three different section lines.

The lithology model Table 4.2 has been prepared under Rockworks 16 platform considering actual lithology encountered in each borehole and assigning same G value for the similar lithology, and thus correlating on the basis of modelling the G value. It is evident from the lithology model of the area that entire area is dominated by surface clay either deep grey or yellow (in limited patches). The occurrences of fine gray sands at the surface have been noticed at very few occasions. The surface clay is followed down by sands of different grade fine to coarse and mostly grey in colour. The grey sediments are underlain by sands and clay of brownish red to yellowish colours. The upper grey sediments are expected to be part of younger alluvium and the lower sediments is older alluvium, younger and older alluvium together comprises the Quaternary alluvium. The Quaternary alluvium is separated by a thick grey persistent clay bed across the study area from the underlying sediment or the Tertiary sediments. The boundary between two is very conspicuous with the occurrences of marker clay bed. The lithology below the grey marker clay is dominated by sand fine to medium to coarse sands and dominantly grey coloured. The Tertiary sediments in the study area characterised by thick granular zones. The first Tertiary sands is followed by a thick dark grey clay and subsequently by 2nd Tertiary sands. Another clay is encountered below the sands at few locations within the depth of 300-325 mbgl. The thickness of the Tertiary sediments increases towards south and southeast.

The disposition of lithology in the study area has been clearly depicted along four sections N-S or Gopalnagar(Kolaghat)-Khejuri section Table 4.3 NW-SE or Ratulia-Haldia section

Table 4.4 WNW- ESE or Fakirganj-Dhenkua Table 4.5 section and E-W or Bolaipanda (Moyna)- Tabakhali section Table 4.6 All sections reveals occurrences of clay at the surface except few area of Kolaghat, Panskura, Moyna and Khejuri II blocks where fine sands are encountered at the surface. The north south disposition indicates that the depth of the marker Tertiary clay increases from north to south, therefore the Tertiary beds are likely to be encountered at greater depth in Chandipur, Nandigram, Khejuri area than that of Kolaghat in the north. Same is witnessed in NW_SE section where the depth Tertiary is more around Haldia area than Panskura. However, the E_W section does not depict much variation in the depth of the stratigraphic sequence, except there may be significant variation in the depth of occurrences of Tertiary across Moyna block, which is required to be studied further detail for inferring about some structural controls, if any. Every section in the area reveals the most extensive significantly thick Tertiary sands within the depth of 300 mbgl.

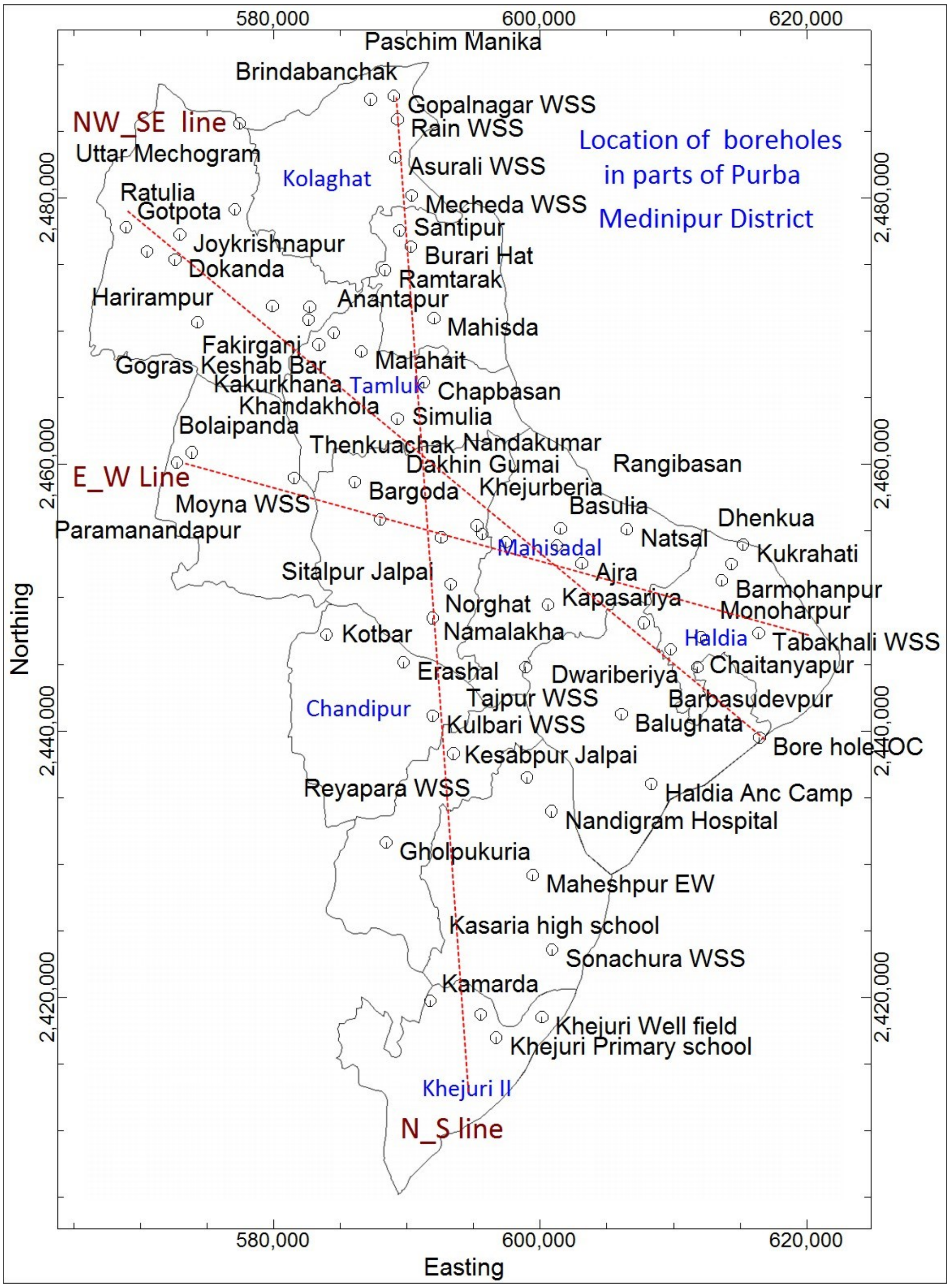


Table 4.1 Location of bore holes and section lines in study area

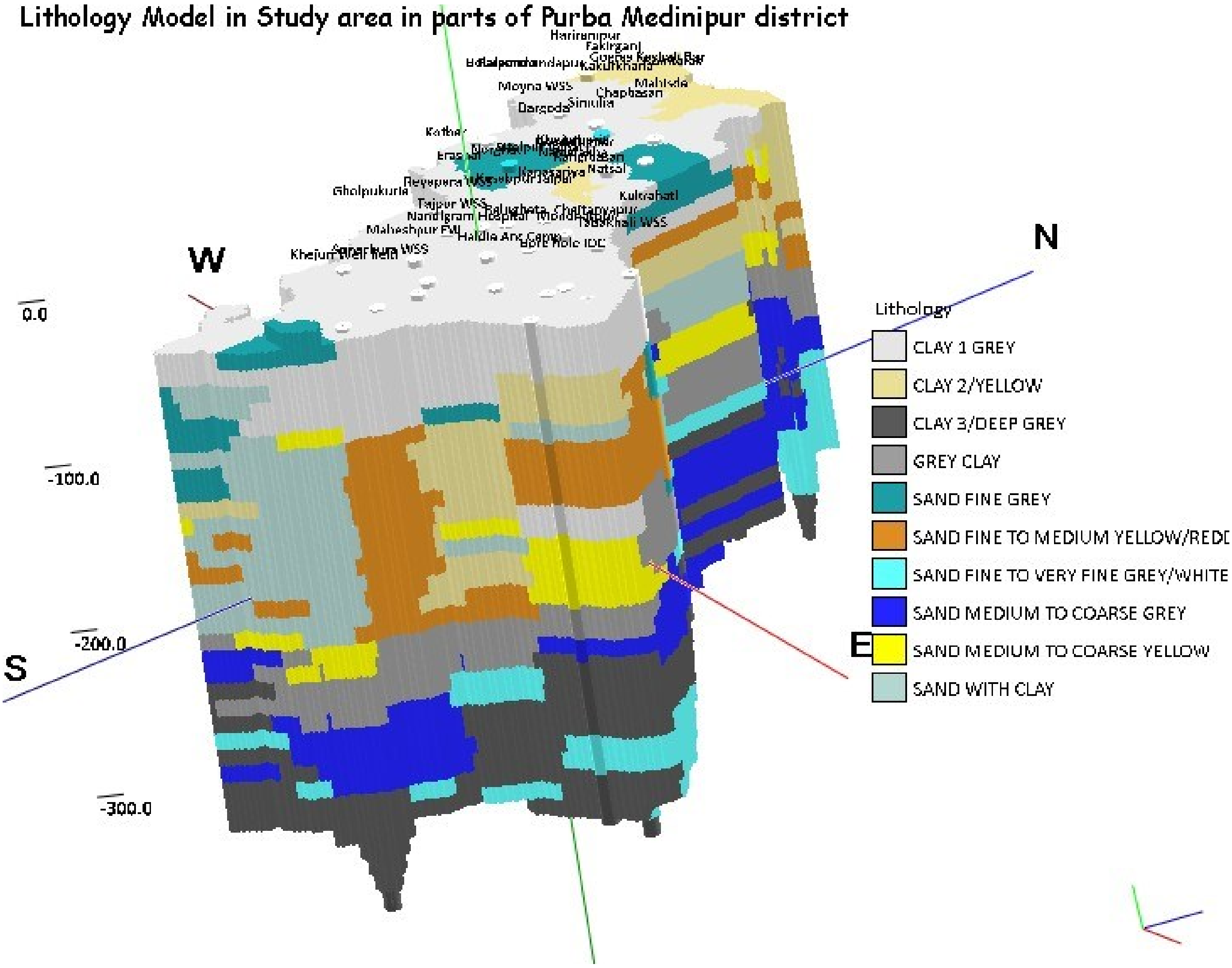


Table 4.2 Lithology Model of the study area

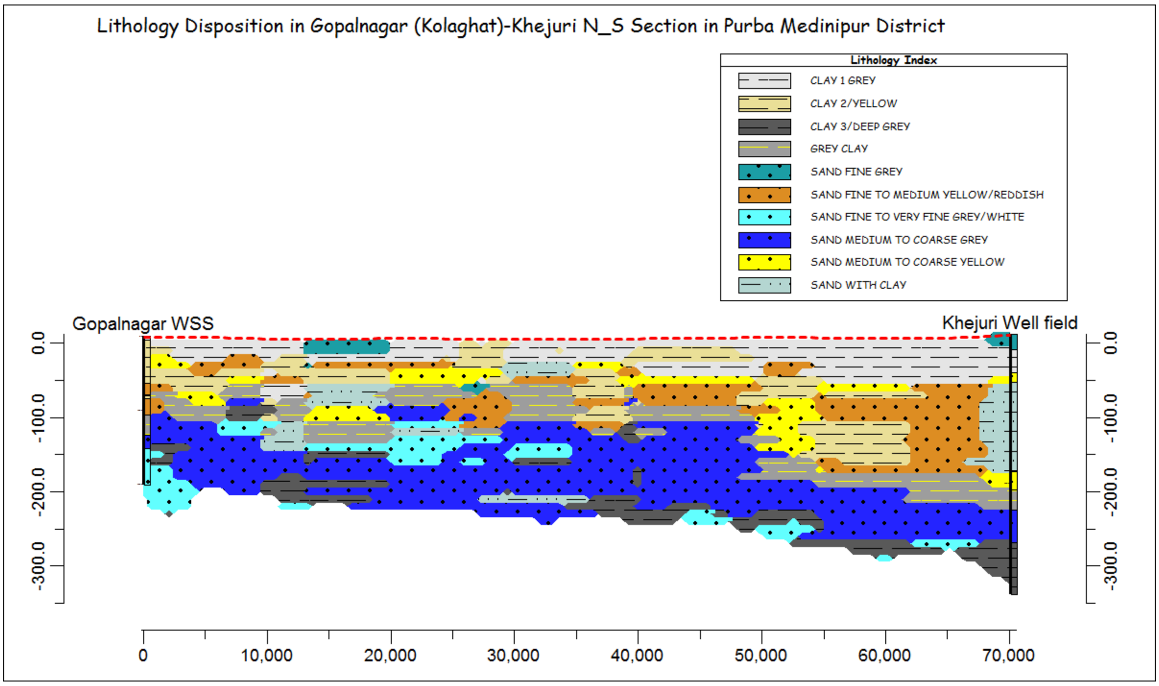


Table 4.3 Lithology disposition Gopalnagar-Khejuri

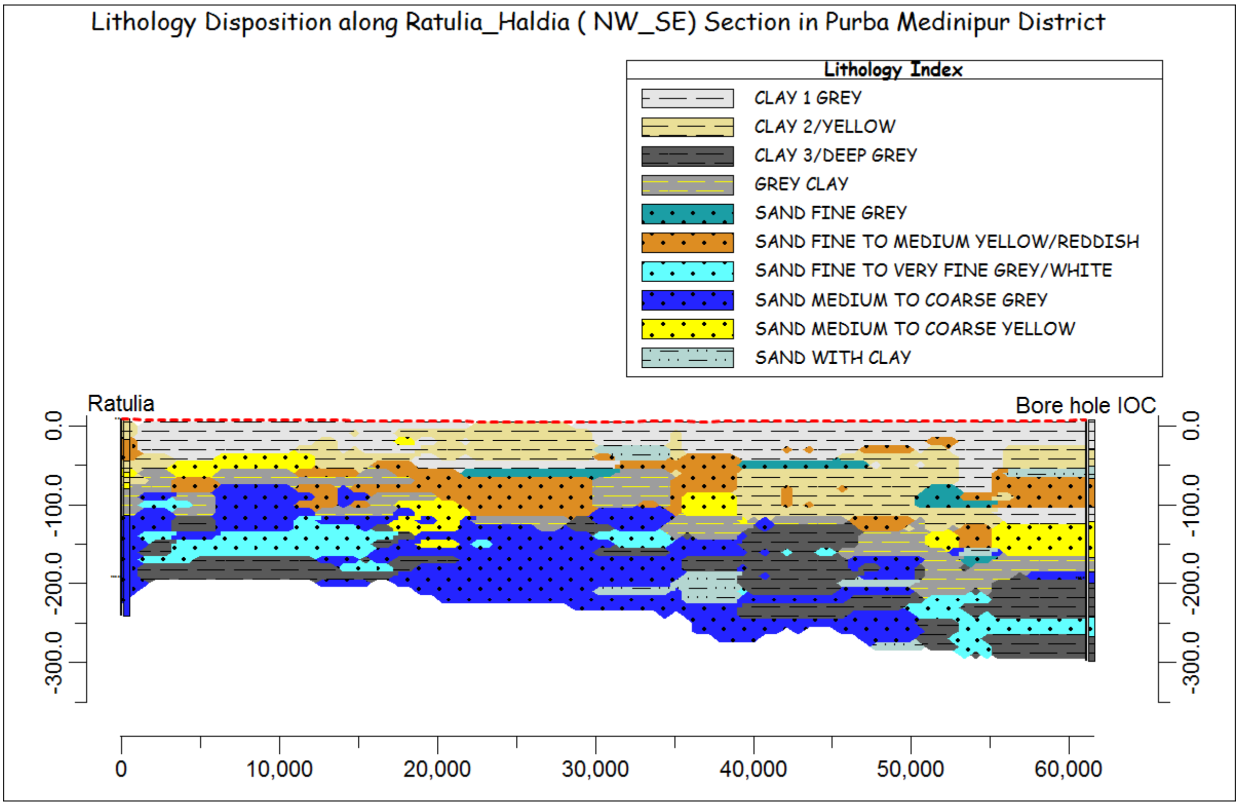


Table 4.4 Lithology disposition Ratulia-Haldia

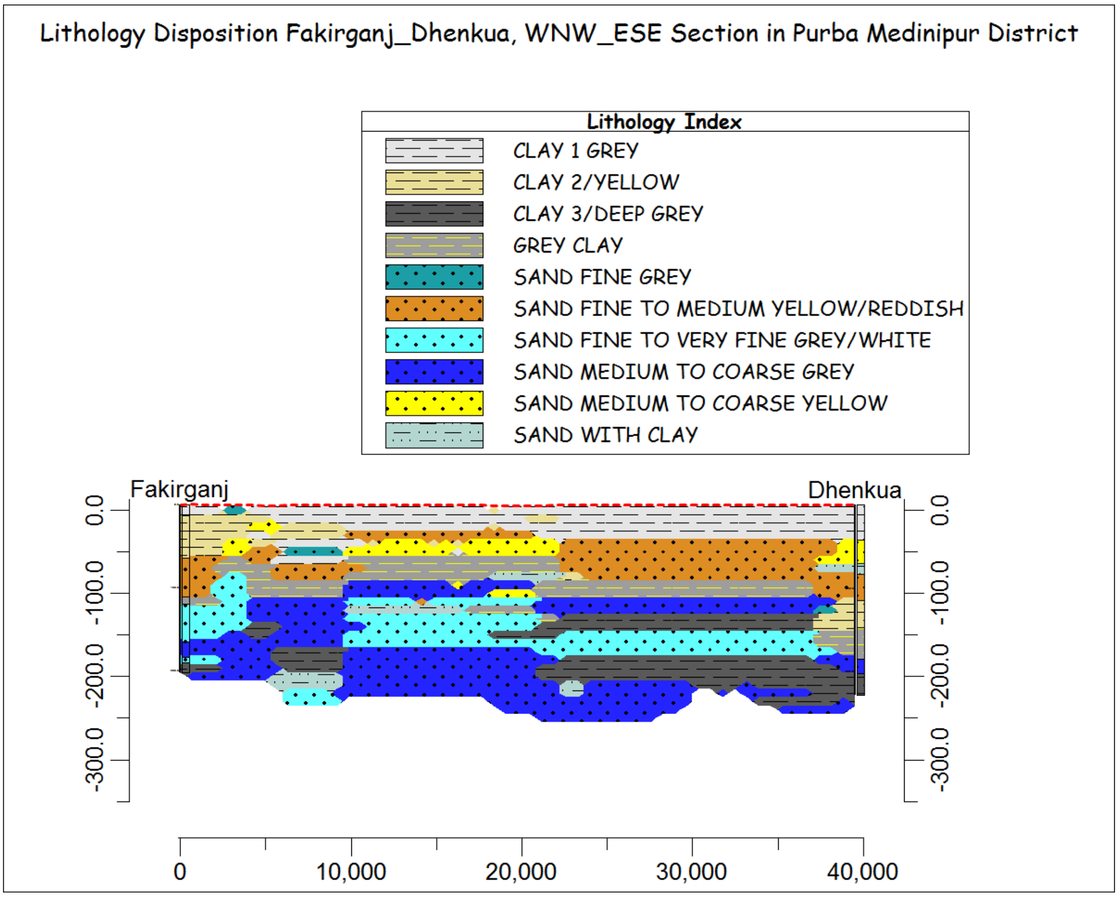


Table 4.5 Lithology disposition Fakirganj-Dhenkua

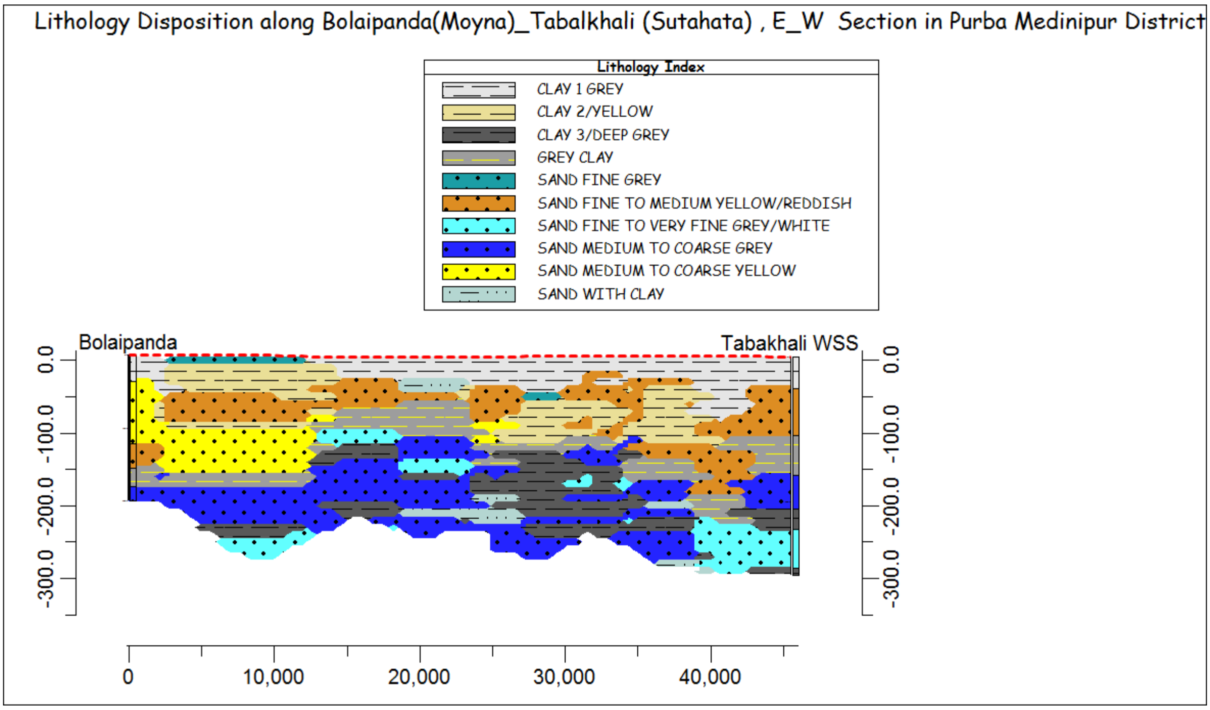


Table 4.6 Lithology disposition Bolaipanda-Tabakhali

4.3 Hydrogeology and Aquifer Disposition

The interpretation, analysis, generalization and subsequent grouping of the granular horizons on the basis of their physical and geological nature, stratigraphic age and continuity leads to differentiate two dominant Aquifer systems. The area is underlain by thick consistent surface clay (clay I) of dominantly gray in colour. The lithological units above the marker Tertiary Clay have been designated as upper litho system and the lithological units below the marker clay has been designated as lower litho system (Ground Water Studies in Kasai Subarnarekha River Basin, CGWB,2012). The granular zones within the upper litho system have been categorised as Quaternary aquifers or Aquifer I and the granular horizons within the lower litho system has been categorised as Tertiary aquifer or Aquifer II. The Quaternary aquifer further splits into two separate aquifers Q1 and Q2 (mostly conforms newer alluvium and older alluvium respectively). The Q2 or the older alluvium aquifer is consistent throughout the study area whereas at places the Q1 is either very thin or absent. Thus, in those area the Aquifer I is represented by older alluvium sands only. The clay II is of mostly older alluvium origin and characterised by yellow to reddish brown in colour, separates Q1 and Q2 (wherever present) within Quaternary Aquifer /Aquifer I.

The occurrences of thick consistent dark clay bed throughout the area mark the beginning of new sedimentation history under different depositional environment, thus indicates the beginning of Tertiary sedimentation in the study area. Followed by the Tertiary clay bed, the granular horizons in the lower lithosystem comprises the Tertiary Aquifer or Aquifer II. The Aquifer II within the depth range of 300-325 mbgl is characterised by occurrences of two prominent sands separated by thick steel gray coloured clay, thus forming two separate aquifer T1 and T2 within the aquifer II. At places pinching out of T1 or T2 has also been witnessed. The lower tertiary sands often followed by another clay bed below. The Tertiary or the aquifer II is very thick, persistent and is believed to be a potential aquifer owing to its continuity and volume.

Besides two prominent aquifer systems the presence of less common, less persistent, comparatively thin granular zones of fine sands are found to occur discontinuously at few patches in the study area. The granular zones of fine sands of 5-10 m thick is encountered at few discrete locations in Kolaghat, Panskura and Sahid Matangini blocks in inlands area and constitutes the dug well zones. The occurrences of dune sands overlying the younger alluvium sediments are found in Khejuri II block. The individual dunes are arcuate shaped with the thickness varies between 10-20 m. The dune sands constitute potential aquifer. Both these,

shallow dug well zones and dune sand aquifers are not regional aquifer in the area and thusmay be termed as Phreatic Aquifer or dune aquifers.

Table 4.7 and Table 4.8 represents two different views of the 3D aquifer model in the study area. The plan view of the model clearly indicates persistent thick surface clay cover throughout the area except one to two discrete locations.

Table 4.9 shows the N-S section of aquifer and aquiclude disposition in the study area. The gradual deepening of Tertiary aquifer from Kolaghat (North) to Khejuri (south) is very distinctive. The NW-SE section also depicts the same for Panskura to Haldia section

Table 4.10. The tertiary aquifers are likely to be encountered at the deeper level only towards the southern and southeastern parts of the study area. The gradual deepening of the Tertiary may be following the basin configuration. The E_W section, Moyna-Tabakhali Table 4.11shows that Tertiary is deeper both in Moyna (eastern parts) and in Tabakhali in Sutahata block. The deep-seated Tertiary at Moyna need to be ascertained further for structural control, if any. The undulating depositional surface throughout the sedimentation history in the area is very characteristics and may be due to erosional surface. The significant thick tertiary sands are very prominent in all the sections indicating potential Tertiary aquifer in the area.

Table shows the disposition and thickness of the individual aquifer system and the Quaternary/Tertiary boundary.

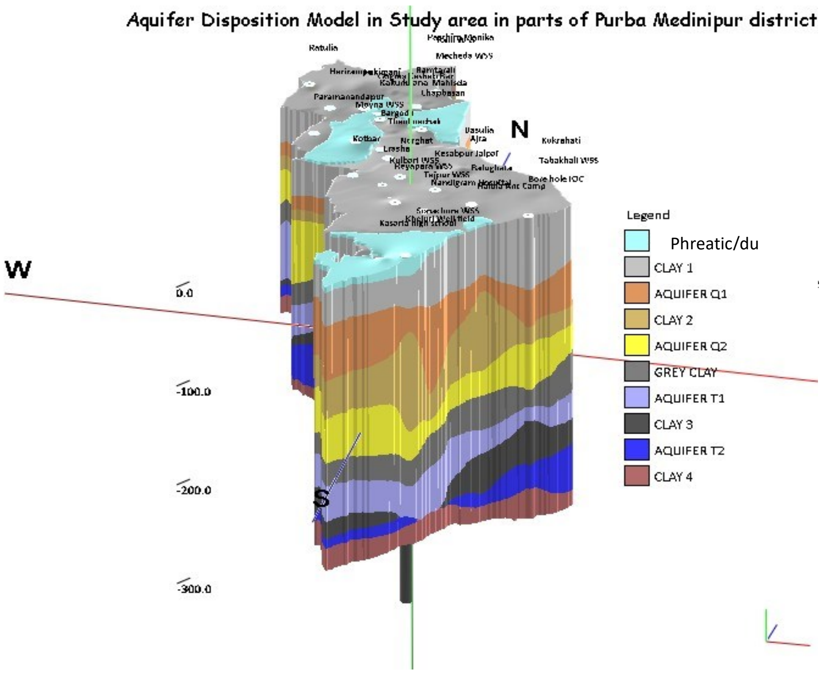


Table 4.7 Aquifer Disposition (a)

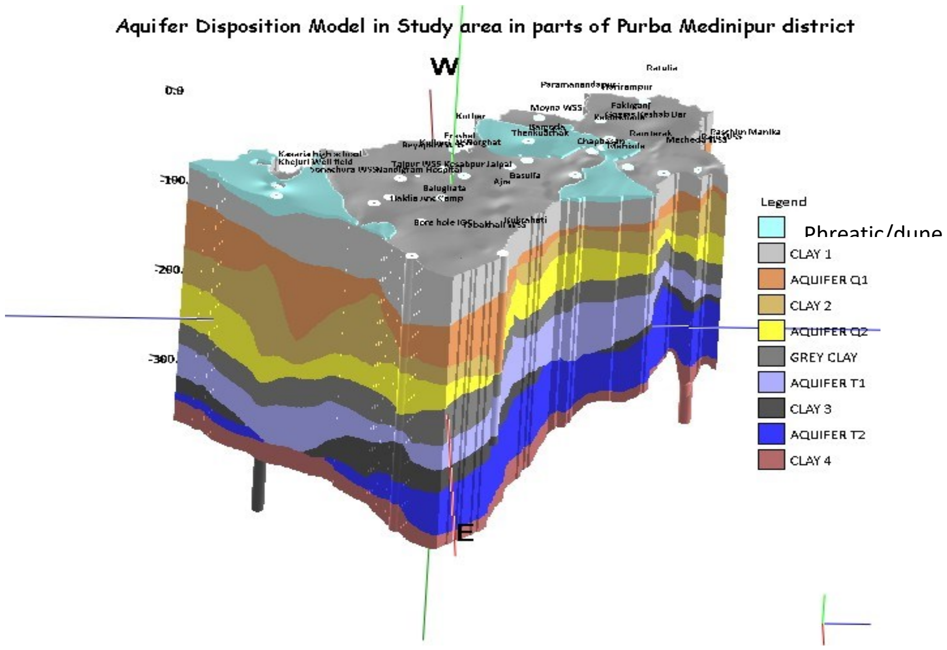


Table 4.8 Aquifer Disposition (b)

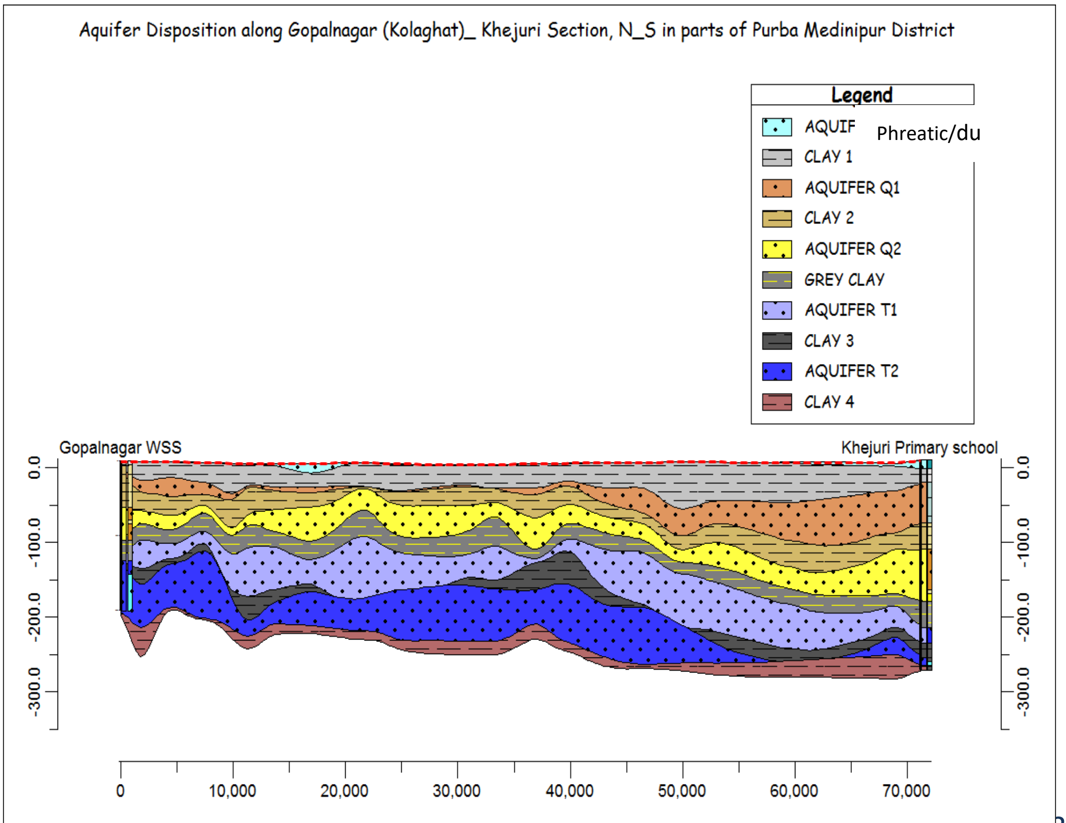


Table 4.9 Aquifer Disposition Gopalnagar-Khejuri

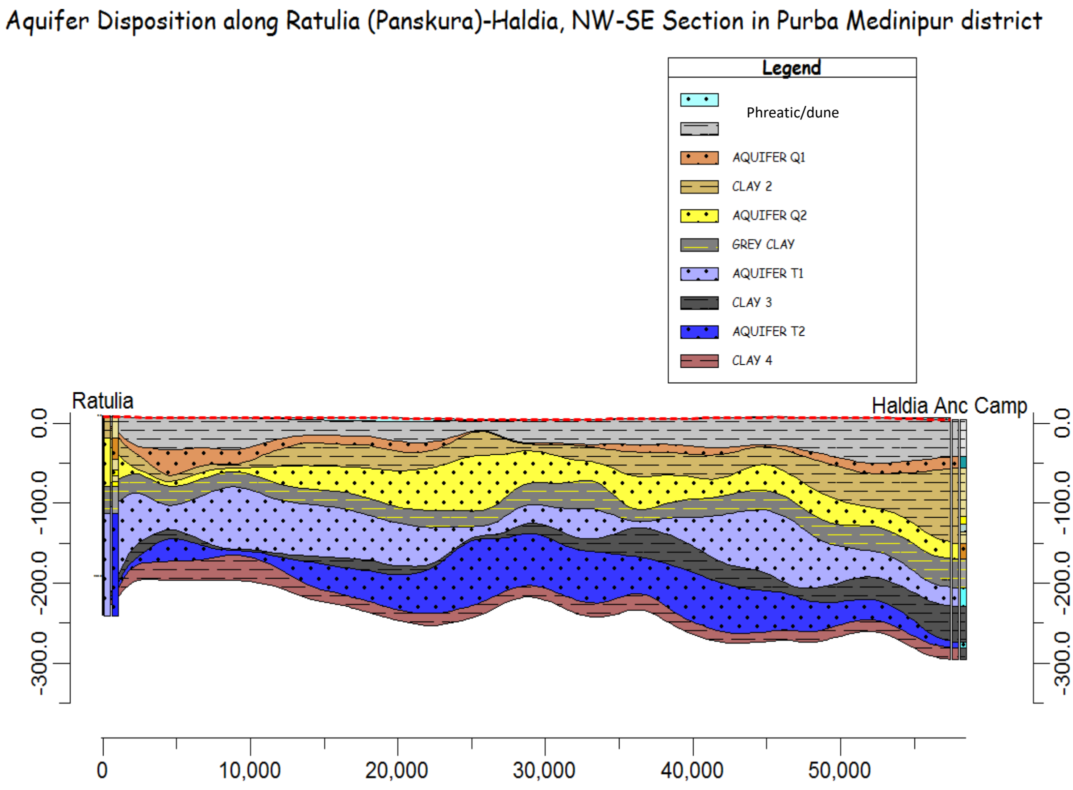


Table 4.10 Aquifer Disposition Ratulia-Haldia section

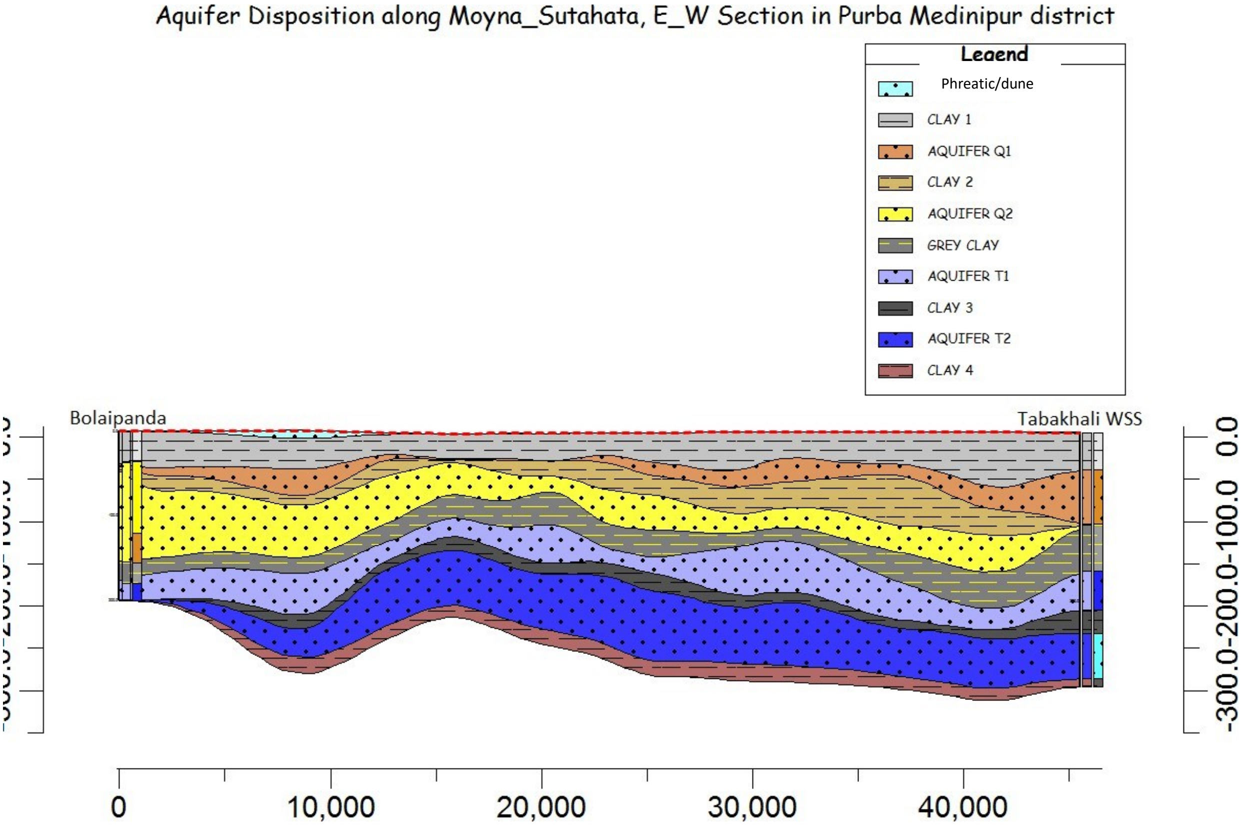


Table 4.11 Aquifer Disposition Moyna-Sutahata

Table 4.12 Disposition of Aquifer System in the study area

Block	Quaternary Aquifers (Aquifer I)									Tertiary Aquifers (Aquifer II)					
	Q1			Q2			Q/T Boundary			T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Kolaghat	28.2	46.31	18.1	67.65	91	23.35	91	112.33	21.33	103.09	128.62	25.54	135.8	203.4	67.6
Panskura	26.75	41.25	19.17	56.56	75.78	34.4	76.11	97.78	21.67	97.78	164.67	66.89	169.67	190.56	37.4
Moyna	44.95	62.43	26.22	75	156	81	156	175	19	175	212	37	218.67	226.67	24
Sahid Matangini	34.75	41	8.33	68.75	98.75	30	98.75	120.25	21.5	120.25	168.75	48.5	185.33	214.33	29
Tamluk	24.67	31.67	14	45.17	82.17	32.4	82.17	106	23.83	105.83	188.67	82.83	199.33	224.67	37.5
Nandakumar	22.43	25.35	3.51	51.5	92.5	41	92.5	117.33	24.83	117.33	131.5	14.17	146.83	235.67	88.83
Mahisadal	44.36	55.94	14.48	78.57	110.43	37.17	110.43	130.86	20.43	130.86	190.86	60	203.8	262.2	58.4
Chanduipur	32.96	65.64	32.68	69.33	89.67	20.33	89.67	114.33	24.67	114.33	175	60.67	184	265	81
Nandigram I & Nandigram II	53	101.2	48.2	117	158.25	41.25	163.6	190.8	27.2	190.8	249.8	59	266	279.25	17.67
Khejuri II	35.33	81.67	46.33	141.67	189.33	47.67	189.33	215.67	26.33	215.67	242.33	26.67	258.5	268	9.5
Haldia and Sutahata	52.24	86.25	34.01	121.61	160.53	38.91	160.53	189.81	29.38	183.27	217.09	33.82	241.38	283.38	42

4.4 Isopach Map:

Thickness of the individual aquiclude and aquifer has been calculated from top and bottom surface of the layers. The equal thickness or the isopach of different layers are shown below.

4.4.1 The clay I (the confining aquiclude)

The thickness in the study area, varies from 20-90 m. The thickness of the clay is within 20-30 m around Panskura, Kolaghat, Sahid Matangini, Tamluk, Nandakumar area. The thickness is more than 60 m and further thick in southern coastal part in and around Haldia, Sutahata, Nandigram area. Thickness of aquiclude I is less in Khejuri II block.

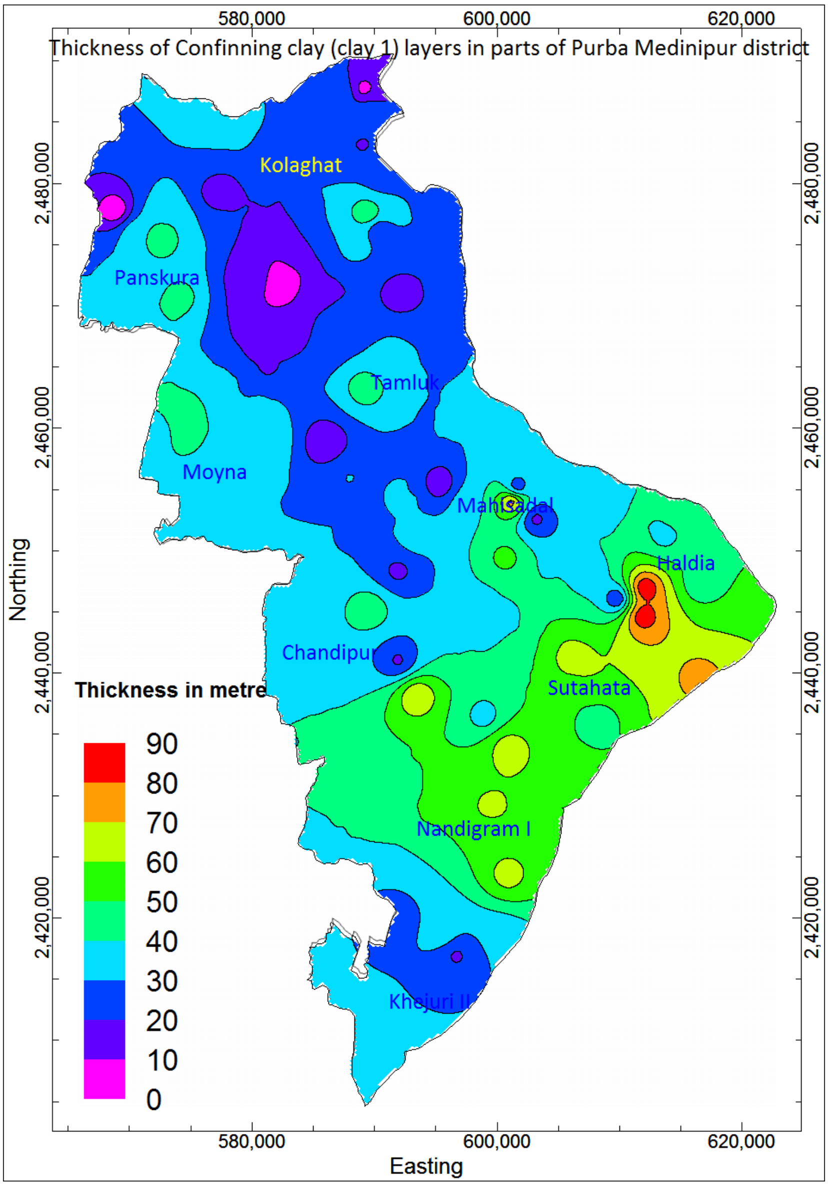


Table 4.13 Isopach of Surface Clay

4.4.2 Thickness of Quaternary /Tertiary boundary Clay/Marker Bed

It varies between 10-50 m. The average thickness is 20-30 m in major part of the area. The thickness is 30-50 m in Haldia and Sutahata block.

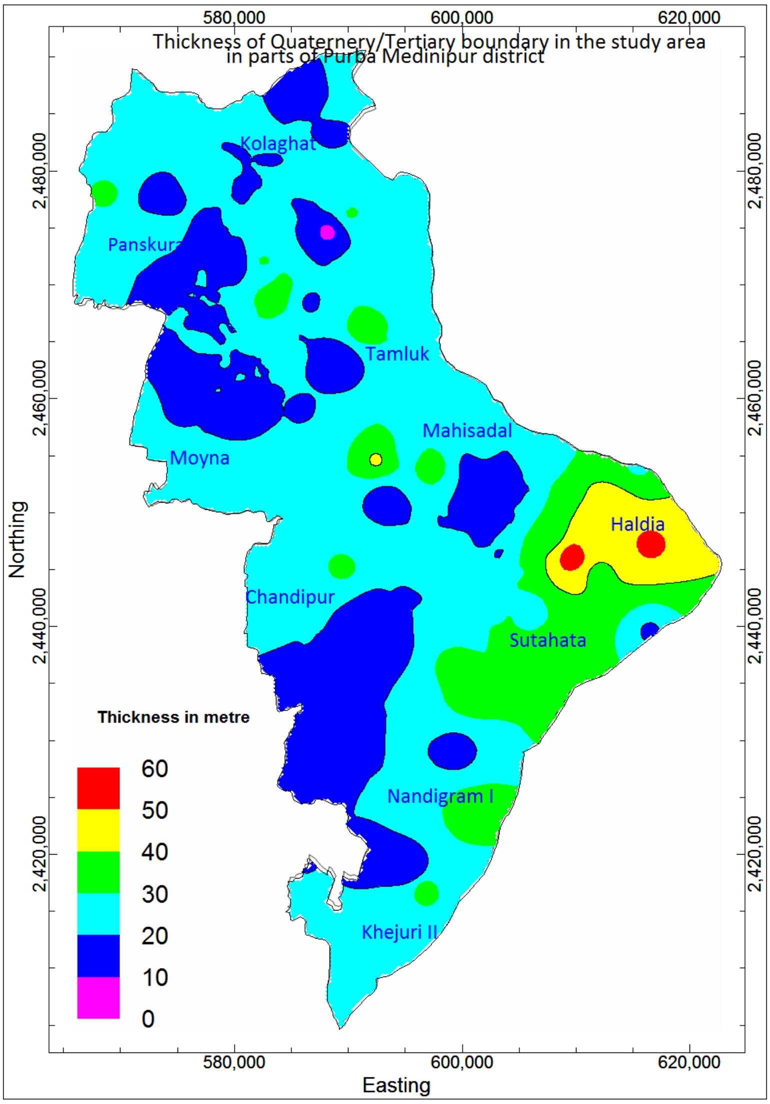
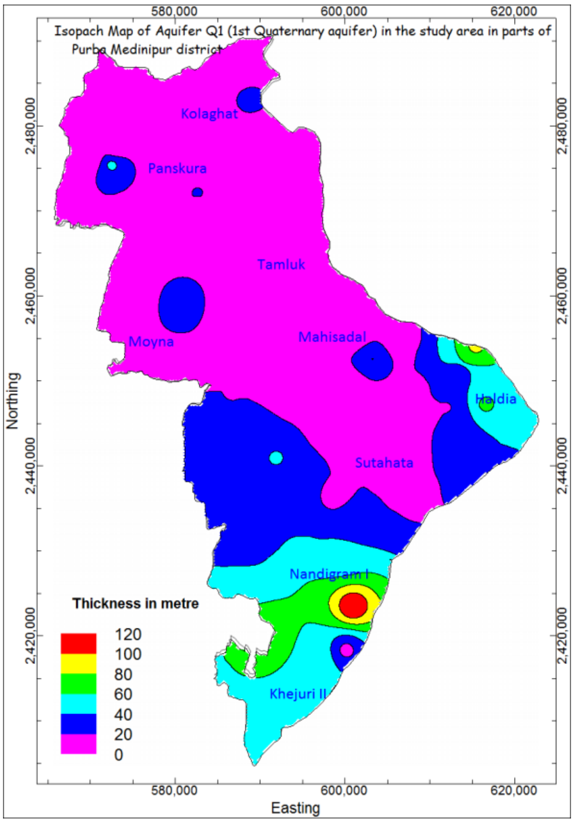


Table 4.14 Isopach of Marker Clay (Q/T)

4.4.3 The isopach maps of Quaternary aquifer or Aquifer I

Table 4.15 shows that the Q1 or the aquifer represented by younger alluvium is less thick with average thinckness within 0-20 m. In contrary to that the Q2 or the aquifer represented by older alluvium is 20-40 m thick in major part of the study area. The thickness of older alluvium sands is further thick 40-80m in Moyna block.



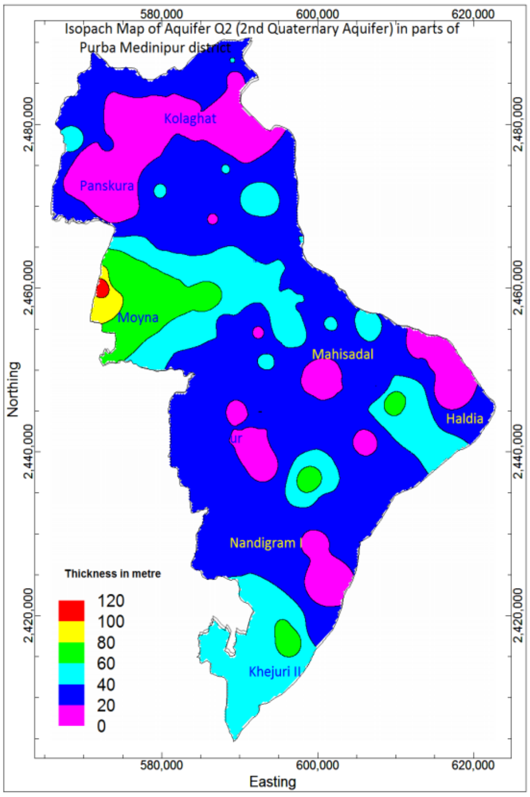


Table 4.15 Isopach of Q1 and Q2

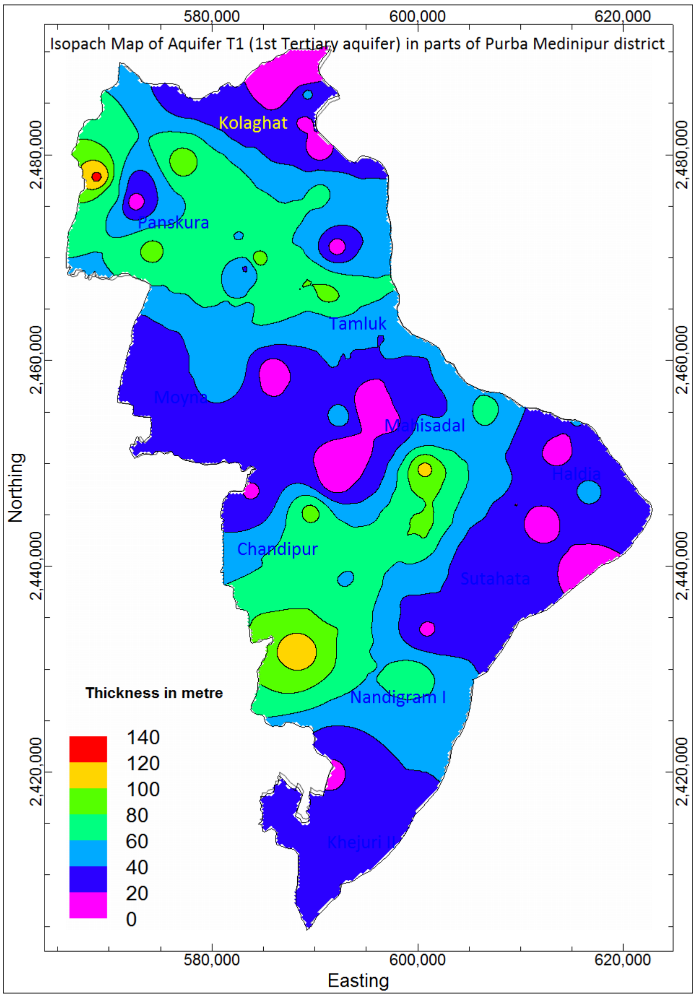


Table 4.16 Isopach of T1

4.4.4 The isopach maps of Tertiary aquifer or Aquifer II

Table 4.16 shows that the thickness of T1 or the first aquifer in Tertiary sediments is fairly thick throughout the area . The average thickness of T1 is 50 m and maximum being around 80 m thick. The 2nd aquifer in Tertiary or T2 is also very thick with average thickness is around 45 m. The cumulative thickness of T1 and T2 varies between 40-140m. In Haldia, Sutahata, Nandigram I, II block the Tertiary aquifer is 60-70 m thick within the mapped depth of 300 m. Thickness of Tertiary is around 40 m in Khejuri II block within the 300 m. In rest of the area the Tertiary aquifer is even thicker.

5.0 HYDROGEOLOGY

5.1 Nature of the Aquifer system:

The principal aquifer in the area is Aquifer I and Aquifer II, representing Quaternary or the upper lithounits and the Tertiary or the lower litho unit respectively. The aquifer-I is dominantly consisting of sands fine to medium and coarse, grey and yellowish brown in colour. The aquifer II is dominated by fine to very fine and medium sands greyish white in colour. Both these aquifers are in semi confined to confined condition. The 3rd aquifer, which is occasionally present in few patches is less persistent thin shallow phreatic aquifer/ dune aquifer.

5.2 Occurrence, movement, and distribution of ground water:

To study the ground water regime of prevailing Aquifer system in the study area, under the data generation activity of the NAQUIM, about 140 observation wells from different aquifer systems has been monitored in the pre and post monsoon period. The observation wells represent different aquifer system from different depth. These are hand pumps, Mark II tube wells, tube wells of water supply schemes of PHED, Govt. of WB, Agri irrigation tube wells, CGWB observation wells, piezometer of State Water Investigation Directorate, Govt. of WB, dug well representing phreatic aquifer etc. The depth of the wells varies from 7 m to 300 m. The observation wells have been categorized and grouped as observation Wells from Quaternary Aquifer System or Aquifer I, Observation Wells from Tertiary Aquifer System or Aquifer II, observation Wells from Phreatic Aquifer. The Tertiary or the aquifer II has been monitored throughout the study area, however, due to occurrences of brackish water in Aquifer I, the wells representing Aquifer I are very limited except the inland blocks. The shallow phreatic aquifer is present in few patches and in dune sands of Khejuri II block.

The water level data of Quaternary Aquifer (Aquifer I) is very limited, mostly concentrated around Kolaghat, Panskura Sahid Matangini block. In coastal blocks due to higher conductivity of the ground water in aquifer I the structures are rare or not in working condition due to brackish water contamination. Extrapolation of the water level data shows that due to heavy Irrigation withdrawal, the water level in Quaternary aquifer is very deep to the extent of 22-25 mbgl in and around Panskura and Kolaghat block. In rest of the study area, it lies within 12-15 mbgl. CGWB exploration in Khejuri II block, however, reveals that the water level in the Quaternary aquifer is shallower and lies at 5-7 mbgl. The less development due to brackish nature of ground water may results in shallow water level of Aquifer I in the area.

The pre-monsoon depth to water level map of the Tertiary aquifer (Aquifer II) shows the water level lies within 15-21 mbgl with few local deepening of water level around Panskura block. In post monsoon time water level in the Tertiary aquifer lies within 11-17 mbgl with local deepening around Sutahata block. The fluctuation of water level between pre and post in Tertiary revels that, in the north-western parts of the study area around Panskura, Moyna block fluctuation is very high to the tune of more than 10 m whereas in the central part is around 5 m and in southern and south eastern parts in the coastal area the fluctuation is even less than 5 m (1-4 m). The seasonal variation in water level reflects the gradient of flow in the aquifer system from recharge to discharge area.

The unconfined aquifer present in few patches and in dune sands are not at all developed either for drinking or for irrigation uses. The static water level in the unconfined aquifer is shallow and lies around 5-7 mbgl around Panskura and in dune sands in Khejuri II block. The water level is even shallower around Sahid Matangini, Tamluk and Sutahata block.

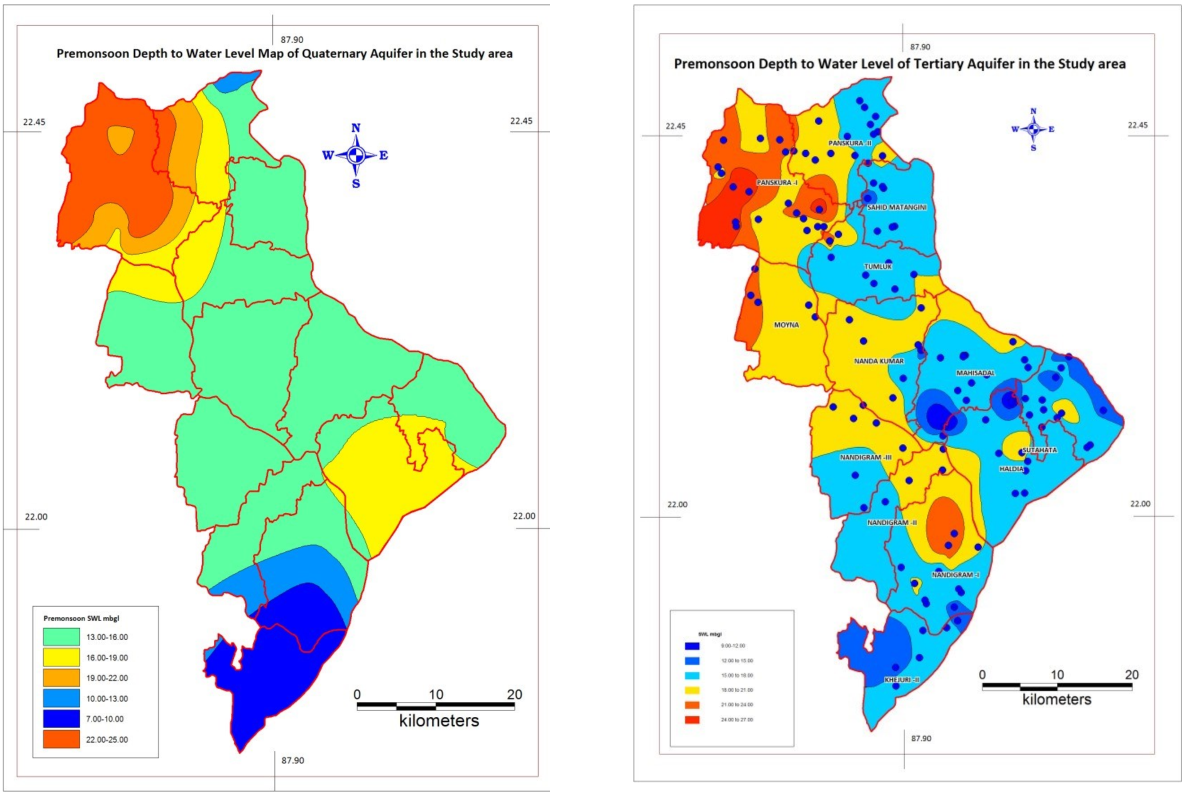
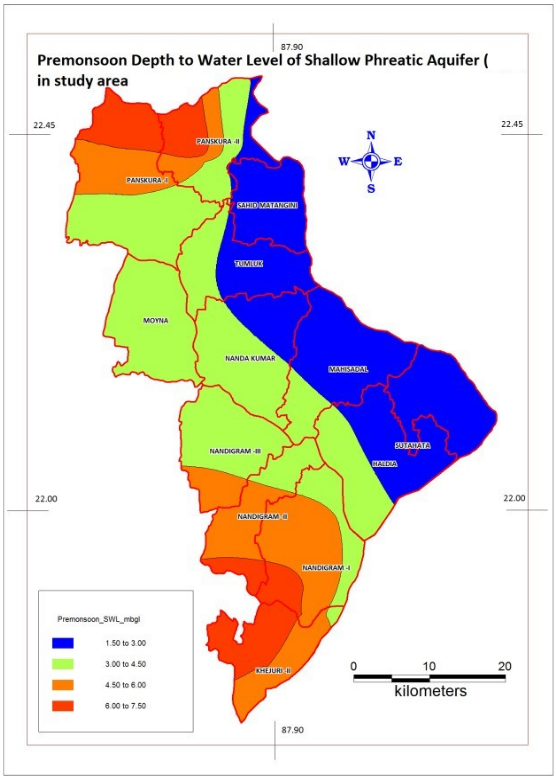


Table 5.1 Pre-Monsoon DTWL of Quaternary and Tertiary aquifer



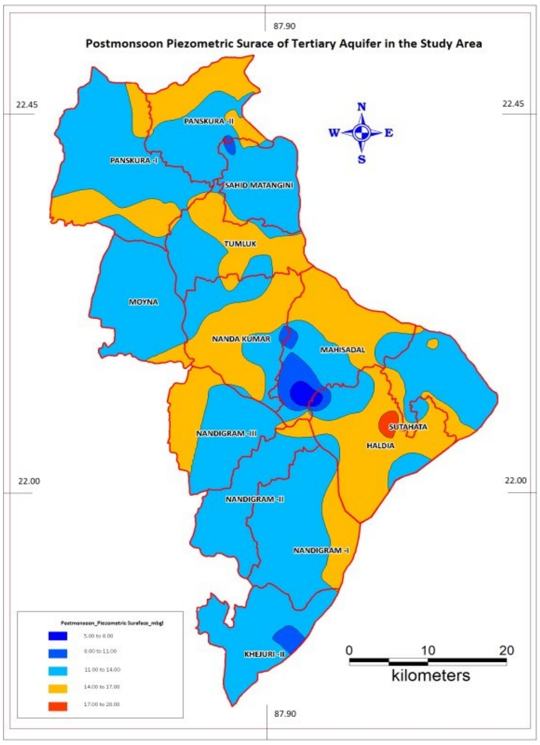


Table 5.2 Pre-monsoon DTWL shallow aquifers(Left)

Table 5.3 post-monsoon peizometric surface of tertiary aquifers(Right)

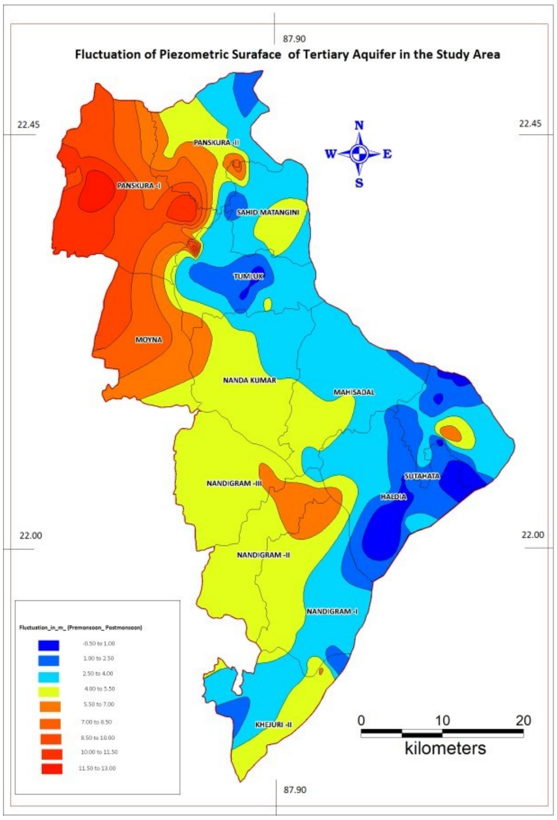


Table 5.4 Fluctuation of piezometric surface of tertiary aquifers

Table 5.5 Observation wells network in the study area:

Sl No	Village	Block_Name	Type_of_Well	Location	Latitude	Longitude	Depth(m bgl)	Pre-monsoon /SWLmbgl	Postmonsoon/SWL mbgl
1	Kotbar	Chandipur	PHED_DTW	Approach from Chuakhali bazar;Kulapara village water tank	22.1280	87.8141	231	18.7	14.2
2	Muradpur	Chandipur	PHED_DTW	Muradpur Village, Backside of Muradpur Vivekananda Vidyapith,approach from Hanschora on Nandigram road	22.0792	87.9040	260	19.4	13.9
3	Rasikchak	Chandipur	PHED_DTW	Approach from Srikrishnapur towardsRasikchak	22.0470	87.8425	270		
4	Ersal	Chandipur	PHED_DTW	Brindabanpur village, Ersal WSS, onNandakumar-Chandipur Road	22.1091	87.8697	280	18.4	13.05
5	Boroj	Chandipur	Mk II/Pvt Tw	Boroj Market compound(58)	22.1300	87.8530	213.59		14.05
6	Haldia Anc Camp	Haldia	CGWB Pz	Towards HQ of Indian Coast Guard	22.0256	88.0497	230	15.54	15.89
7	Balughata	Haldia	Mk II/Pvt Tw	Primary School	22.0731	88.0283	250	18	14.5
8	Haldia Township	Haldia	Mk II/Pvt Tw	From Helipad towards bus stand,besides quarter RHS of road.	22.0260	88.0617	270	16.18	13.25
9	Barsunda	Haldia	PHED_DTW	Haldia Mecheda Highway, BesidesNH-41; TW 2	22.1129	88.0114	280	16.7	13.6
10	Solat	Haldia	PHED_DTW	On Haldia_ Highway	22.0739	88.0581	280	20.6	19.65
11	Dwariberiya	Haldia	PHED_DTW	Inside village Hadia, approach fromDwariberiya Market	22.1347	88.0449	283	10.8	
				Approach from City Centre; Monoharpur_Chaitnyapur				15.8	

12	Monoharpur	Haldia	PHED_DTW	road (moram road) TW 1	22.1043	88.0839	294		12.8
13	Balughata	Haldia	CGWB Pz	Primary School	22.0731	88.0283	295	17.6	14.36
14	Deulpota Purbapara	Haldia	Mk II/Pvt Tw	Deulpota Purbapara	22.1379	88.0626	279.3	16.25	14.15
15	Hospital Housing Complex,Durgachak.	Haldia	Mk II/Pvt Tw	Hospital Housing Complex,Durgachak.	22.0803	88.1427	300	15.3	14.9
16	Deulpota G.P. Office	Haldia	Mk II/Pvt Tw	Deulpota G.P. Office	22.1186	88.0678	279.3	16.5	14.75
17	Tetulberia Primary School Premises	Haldia	SWID PZ	Tetulberia Primary School Premises	22.0637	88.0656	241.15	16.36	14.77
18	Kishorepur Primary School Premises	Haldia	Mk II/Pvt Tw	Kishorepur Primary Sachool Premises	22.0526	88.0631	296	16	15.85
19	CPT Qtr.no 5/65	Haldia	Mk II/Pvt Tw	CPT Qtr.no 5/65	22.0253	88.0659	130	17	16.15
20	Kamarda	Khejuri I	Mk II/Pvt Tw	Putimari Vivekananda Sishu Siksha kendra	21.9380	87.9020	201	15.8	
21	Padurveri	Khejuri II	Mk II/Pvt Tw	On Nijkasba Boga road, Podurveri Sabuj Sangha	21.8086	87.9020	10	5.8	
22	Kastala	Khejuri II	Mk II/Pvt Tw	NHS CGWB, Kastala Sishu Sikshakendra,on Heria Bogard Road	21.8950	87.9344	180	15.5	12.28
23	Sundarpur (South Baga)	Khejuri II	Mk II/Pvt Tw	On Baga Nijkasba road; Sundarpur Madhyampara Sishu Siksha Kendra	21.8193	87.8946	220	12.9	11.7
24	Sherkhan Chak	Khejuri II	Mk II/Pvt Tw	NHS CGWB	21.9331	87.9505	230	16.3	12.81

25	Ramchak	Khejuri II	Mk II/Pvt Tw	Road side near the house of Manindra Manna	21.8990	87.9327	230	16.6	12.83
26	Khejuri	Khejuri II	Mk II/Pvt Tw	NHS CGWB, Anukul Ashram	21.8746	87.9750	230	13.45	12.21
27	Maldaha	Khejuri II	Mk II/Pvt Tw	Maldaha Primary School	21.9190	87.9192	276.58	18.6	13.35
28	Monoharchak	Khejuri II	Mk II/Pvt Tw	Khejuri Adarsha Vidyapith Premises	21.8630	87.9302	217.34	16.5	13.7
29	Lakshmanchak	Khejuri II	Mk II/Pvt Tw	Lakshmanchak Primary School	21.8308	87.9256	229.3	16	10.7
30	Khejuri	Khejuri II	P.TUBE	Khejuri Ramkrishan Swarasati Primary School	21.8663	87.9609	230.49	17.76	12.22
31	Nijkasba	Khejuri II	AI_DTW	Nijkasba Village,(A.I.) Pump House(119)	21.7975	87.8952	200	17.3	13
32	Diglabad	Kolaghat	DW	NHS	22.4205	87.7854	25	5.1	2.15
33	Siddha	Kolaghat	Mk II/Pvt Tw	In the House of Nemai Betal, near Siddha High School	22.4255	87.7858	30	7.4	4.9
34	Gurchakli (Sitala mandir)	Kolaghat	Mk II/Pvt Tw	Sitala Mandir	22.4286	87.7783	120	17.7	13.1
35	Kolaghat	Kolaghat	Mk II/Pvt Tw	BDO office	22.4542	87.8717	120	16.65	13.23
36	Khadinan (No 8)	Kolaghat	AI_DTW	On Khadinan Manika road	22.4831	87.8545	130	15.6	
37	Mecheda CGWB	Kolaghat	CGWB Pz	Gopinath School	22.4170	87.8590	130	17.6	10.06
38	Bathanberia	Kolaghat	PHED_DTW	Faridpur	22.4723	87.8688	180	16.9	14.5
39	Asurali Kolaghat	Kolaghat	PHED_DTW	Approach from Kolaghat towards Asurali before crossing the Pool.	22.4515	87.8661	182	17.1	14.6
40	Mecheda	Kolaghat	PHED_DTW	Mahisgoat PHED WSS; 5 No thermal gate Pump 2	22.4258	87.8778	192	19.1	15.7
41	Kolaghat	Kolaghat	DW	Jain temple, NHS	22.4435	87.8763	11	2.7	1.93

42	Gopalnagar	Kolaghat	Mk II/Pvt Tw	Gopalnagar(70)G.P.Office,Siddha-II G.P.	22.4316	87.7633	137.1	20.65	14.1
43	Siddha	Kolaghat	Mk II/Pvt Tw	Siddha (227) bazar	22.4210	87.7910	112.776	20.15	13.05
44	Mandergechia	Kolaghat	SWID PZ	Mandargachiya(301),Sagarbar G.P.	22.4263	87.8423	101.3	18.05	12.65
45	Pulsita	Kolaghat	Mk II/Pvt Tw	Pulsita (296),Kamarhati,Pulsita G.P.	22.4487	87.8323	121	17.75	13.3
46	Jadupur	Kolaghat	Mk II/Pvt Tw	Jadupur (244),Karasala,Bridabanchak G.P.	22.4672	87.7952	146.3	19.2	15
47	Boradingi	Kolaghat	SWID PZ	Borodangri(285),Chatinda	22.4629	87.8624	115.16	15.93	12.31
48	Gopalnagar	Kolaghat	SWID PZ	Machinan Gopalnagar(273)	22.4906	87.8624	69.65	14.5	11.09
49	Kulhanda	Kolaghat	SWID PZ	Kulhanda(266),Jadupur,'Baisnabchawk G.P.	22.5096	87.8584	64.16	10.17	6.36
50	Mahisadal	Mahisadal	DW	In the house of Dr. C R Mondal, Mahisadal Geonkhali rd	22.1892	87.9849	7	2.75	1.5
51	Mahisadal	Mahisadal	DTW_submessibl e	In the house of Dr. C R Mondal, Mahisadal Geonkhali rd	22.1892	87.9849	210		
52	Mahisadal B.D.O.	Mahisadal	SWID PZ	Back side of Mahisadal B.D.O.	22.1891	87.9827	234	18.84	15.14
53	Geonkhali	Mahisadal	Mk II/Pvt Tw	Irrigation Bunglow Geonkhali	22.2056	88.0464	248	18.3	15.8
54	Chakgajipur	Mahisadal	Mk II/Pvt Tw	Chakgajipur Masuria Primary School	22.1662	88.0128	168	17.2	14.35
55	Agradut Club	Mahisadal	SWID PZ	Agradut Club Premises	22.1362	87.9862	229.9	17.9	13.78
56	Champi	Mahisadal	Mk II/Pvt Tw	Champi SSK	22.1565	87.9930	210	17.75	13.2
				Near Lakhya; On Mahidasal Nandakumar Road, 3 km				17	

57	Jalsai	Mahisadal	Mk II/Pvt Tw	before Nandakumar, opposite to S/M Enterprise	22.1864	87.9529	210		
58	Bethkundu	Mahisadal	PHED_DTW	Inn Hirarampur village; TW 1	22.1748	88.0660	230	15.5	12.45
59	Kesabpur Jalpai	Mahisadal	CGWB Pz	Primary School	22.1053	87.9588	245	9.4	5.34
60	Tentulberia	Mahisadal	DTW_submessibl e	Tentulberia High school	22.1840	88.0618	260		
61	Rangibasan TW 2	Mahisadal	PHED_DTW	Mahisadal Bazar	22.1877	87.9822	265	15.5	13.4
62	Paramanandapur Pz	Moyna	SWID PZ	Paramanandapur Vevekananda Kanya Vidyapith	22.2455	87.7073	90	15.7	12.3
63	Paramanandapur	Moyna	DTW_submessibl e	Paramanandapur Vevekananda Kanya Vidyapith	22.2455	87.7073	130		
64	Paramanandapur WSS	Moyna	PHED_DTW	Approach from Shyama Bakery	22.2522	87.7166	191	21.1	12.4
65	Dakhin Mayna	Moyna	PHED_DTW	1/2 Panchayet office, Moyna WSS	22.2346	87.7910	204	20.3	13.5
66	Khejurberia	Nandakumar	CGWB Pz	Khejurberia PHC	22.1955	87.9284	190	8.9	5.48
67	Thenkuachak	Nandakumar	Mk II/Pvt Tw	Village Saoraberia Jalpai, Thenkuachak Zone I	22.2061	87.8535	199	18.9	14.2
68	Bargodagodar	Nandakumar	PHED_DTW	Approach from S Pool on Tamluk- Mayna Road	22.2316	87.8350	210	18.6	13.3
69	Sitalpur (Jalpai)	Nandakumar	PHED_DTW	In the village Sitalpur, Jalpai WSS PH 1	22.1619	87.9045	210	16.8	12.3
70	Khejurberia	Nandakumar	PHED_DTW	Tamluk-Nandakumar Road PH 2	22.2016	87.9240	222	18.4	15.3

71	Norghat	Nandakumar	CGWB Pz	PWD compound	22.1389	87.8912	236	19.3	15.21
72	Tarageria(51),	Nandakumar	Mk II/Pvt Tw	Tarageria(51),	22.2456	87.9277	182	18.1	
73	Khejurberia	Nandakumar	Mk II/Pvt Tw	Khejurberia	22.1956	87.9274	191	18.65	14.55
74	Nandigram-I B.D.O.	Nandigram I	SWID PZ	Nandigram-I B.D.O.	22.0083	87.9767	93	15.15	14.2
75	9 No. Garh chakraberia	Nandigram I	Mk II/Pvt Tw	9 No. Garh chakraberia	21.9619	88.0015	279.4		14.7
76	Sonachura Village	Nandigram I	Mk II/Pvt Tw	Sonachura Village	21.9084	87.9795	286.47		15.6
77	Sonachura PH 2	Nandigram I	PHED_DTW	Near Sonachura High School, pump I	21.9124	87.9763	267	15.6	11.6
78	Maheshpur	Nandigram I	CGWB_OW	Maheshpur high school	21.9640	87.9630	267	22.3	
79	Uttar Boyal	Nandigram II	Mk II/Pvt Tw	NHS	22.0782	87.9564	180	18.2	14.91
80	Gholpukur	Nandigram II	PHED_DTW	Village Hanu Bhuyan;On Reyapara Gholpukur road	22.0156	87.8816	229	17.5	12.6
81	Narayanchak	Nandigram II	SWID PZ	Narayanchak High School	22.0819	87.9409	103	15.93	12.73
82	Mongalchak	Nandigram II	Mk II/Pvt Tw	Mongalchak Char Village Towards Adudsmriti Primary School	22.0940	87.9559	223.9	17.55	14.7
83	Asadtala	Nandigram II	SWID PZ	Asadtala Vinod Vidyapith School	22.0535	87.9554	231	20	13.35
84	Khodambari	Nandigram II	Mk II/Pvt Tw	Khodambari Union B.P.H.S.	22.0407	87.9124	214		13.35
85	Rukminipur	Nandigram II	Mk II/Pvt Tw	Barachira P.B.High School, Rukminipu	22.0088	87.8538	280		13.9
86	Gumai	Panskura	Mk II/Pvt Tw	Naer Gumai Sitalamandir and DTW	22.3694	87.7560	120	20.7	12.25
				(AI)					

87	Nilmoni Ramchak	Panskura	AI_DTW	Approach from Haur	22.3506	87.7173	135	19.9	
88	Ratulia	Panskura	CGWB EW	NHS CGWB	22.4052	87.6693	135	19.6	11
89	Ratulia Dolbar	Panskura	AI_DTW	Inside village Dolbar, Approach from Ratulia on NH.	22.4127	87.6649	137	22.6	11.75
90	Gotpota	Panskura	AI_DTW	In the irrigation field	22.3888	87.6845	143	26.5	13.5
91	Deulbrah	Panskura	AI_DTW	On NH,LHS of Panskura Kolaghat road	22.4287	87.8107	155		
92	Hatisal	Panskura	AI_DTW	On Mechogram-Ghatal road	22.4446	87.7447	160	23	
93	Gopimohanpur	Panskura	AI_DTW	Gosaibar village	22.4466	87.7197	180	20	
94	Gobindanagar	Panskura	PHED_DTW	North from Ratulia towards Gobindanagar	22.4445	87.6720	180	22.1	12.4
95	Fakirganj	Panskura	AI_DTW	Fakirganj Bottola Stop	22.3512	87.7758	189	20.2	12.2
96	Gogras Keshab Bar *	Panskura	PHED_DTW	Biri Dokan Bus stop	22.3419	87.8020	200	19.45	13.7
97	Jiyakhali	Panskura		Jyakhali (40),'Kesapat G.P.Jaykhali Pru.School	22.4587	87.7518	70.6	22.93	10.8
98	Gosaibari	Panskura		Gopimohanpur(53),G.bazar,'K esapat G.P.	22.4472	87.7194	73.18	21.25	15
99	S.S. Patna	Panskura	SWID PZ	S.S.Patna Bazar(6),'Mysora G.P.	22.4670	87.6871		22.8	16.3
100	Ratulia	Panskura	Mk II/Pvt Tw	Ratulia Bazar(122),Gobindapur G.P.	22.4060	87.6681	67.06	24.8	15.85
101	Hour	Panskura	Mk II/Pvt Tw	Haur(144) Rly. Station,Ghoshpur G.P.	22.3693	87.6561	68.89	24.15	12.25
102	Amdan	Panskura	Mk II/Pvt Tw	Amdan (158),'Haur G.P.	22.3470	87.6879	95.14	24.6	14.2
103	Radhaban	Panskura	SWID PZ	Radhaban (185),Chatannyapur-I G.P.	22.3354	87.7160	48.4	18.92	

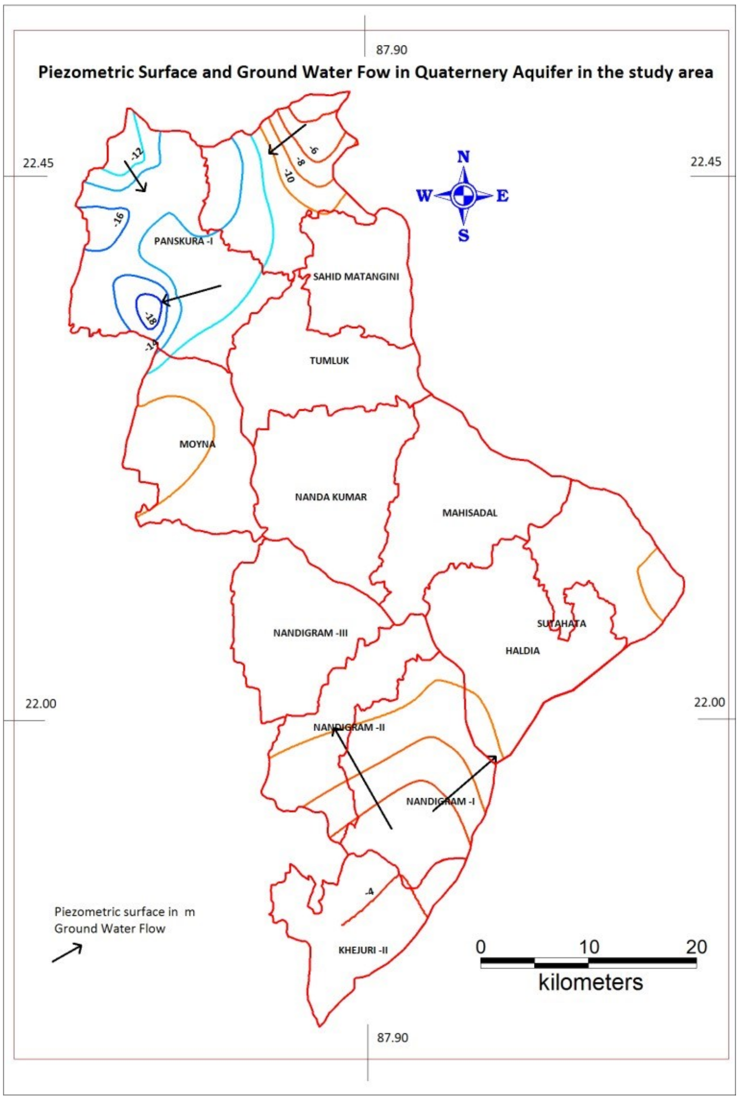
104	Balidangri	Panskura	SWID PZ	Pakskura-I B.D.O.,Beldangri G.P.(86)	22.3910	87.7245	81.9	23.02	13.7
105	Jhikuria	Panskura	Mk II/Pvt Tw	Jhikuria (199),Mahisadal,Pratap-II G.P.	22.3560	87.7381	88.58	24.7	15.75
106	Purusottampur	Panskura	Mk II/Pvt Tw	Baidioari(354),Purusotampur G.P.	22.3373	87.7800	124.67		14.95
107	Purbaitara	Panskura	Mk II/Pvt Tw	Purbasuptiya P.Sch.(325),Raghunathbari G.P.	22.3621	87.7961	137.2	24.5	13.2
108	Harijhama	Panskura	SWID PZ	Harijhama(338),Purusotampur G.P.	22.3581	87.7667	94.3	22.8	13.05
109	Santipur prbapara	Sahid Matangini	DW	In the house of Swapan kr Samanta, oppoosite Regal GH	22.4006	87.8710	15	2.4	0.85
110	Chatra Pz	Sahid Matangini	SWID PZ	Back side of BDO office	22.3826	87.8811	61	15.3	11.9
111	Chatra	Sahid Matangini	PHED_DTW	Naer block office compound, PH 2	22.3874	87.8791	170	15.3	12.1
112	Dariala	Sahid Matangini	AI_DTW	Besides Santipur 2 No Gp office approach from Burari village.	22.3934	87.8661	173		
113	Mahisda	Sahid Matangini	PHED_DTW	Mahisda Zone I Pump 2, on Mecheda Tamluk road	22.3422	87.8935	195	16.4	12
114	Hokhali	Sutahata	DW	Bharat Sevashram Sangha	22.1255	88.1629	20	1.85	1.05
115	Basudevpur	Sutahata	CGWB Pz	Basudevpur High School	22.0831	88.1464	200	16.59	13.42
116	Dhenkua	Sutahata	PHED_DTW	TW I; On Chaitnyapur Kakurhati road, Dighirpar; Morning Salinity reported	22.1744	88.1091	204	16.5	14.4
117	Hokhali	Sutahata	Mk II/Pvt Tw	Mistripara Near Horkhali Ashram	22.1239	88.1634	220	14.7	11.5
118	Chaitnyapur	Sutahata	DTW_submessibl	PWD compound	22.1362	88.0843	240	16.4	13.66

			e						
119	Basudevpur	Sutahata	Mk II/Pvt Tw	Basudevpur High School	22.0831	88.1464	240		
120	Barmohanpur	Sutahata	SWID PZ	Barmohonpur Primary school at Harinvasa	22.1631	88.1019	267		
121	Asadtalia	Sutahata	PHED_DTW	Aprroach from Sutahata PS to Haldia township approach road	22.1154	88.1036	282	15.15	14.5
122	Chaitnyapur Zone II (Bhupatinagar)	Sutahata	PHED_DTW	Bhupatinagar Village adjacent to Bhupatinagar high school, Zone II, Pump II	22.1250	88.0865	287	15.4	12.7
123	Sutahata	Sutahata	CGWB Pz	Police Station	22.1206	88.1093	192	19.8	13.52
124	Sutahata	Sutahata	Mk II/Pvt Tw	Sutahata	22.1192	88.1167	135	16	14.5
125	Krisnanagar	Sutahata	Mk II/Pvt Tw	Krisnanagar	22.1429	88.1187	196	14.65	14.25
126	Parbatipur	Sutahata	Mk II/Pvt Tw	Parbatipur	22.1274	88.1629	133.3	10.45	14.45
127	Harinvasa	Sutahata	SWID PZ	Harinvasa	22.1634	88.1017	309.22	13.42	12.73
128	Anarnagar	Sutahata	Mk II/Pvt Tw	Anarnagar	22.1877	88.1187	279.88	14.2	13.65
129	Tamluk	Tamluk	DTW_submessibl e	PWD compound, Hospital More	22.2851	87.9186	120	18	14.35
130	Ananatapur	Tamluk	CGWB Pz	In the campus of BPHC	22.3329	87.8206	140	18.8	15.06
131	Kakurkhana	Tamluk	AI_DTW	Tamluk-Panskura road, Ramsura stop	22.3250	87.8094	150	24.4	13.85
132	Ramtarak	Tamluk	Mk II/Pvt Tw	NHS	22.3754	87.8585	150	14.74	12.92
133	Malehait	Tamluk	SWID PZ	Malehait Vivekananda Vidyapith	22.1144	87.8405	170		
134	Anantapur zone II	Tamluk	PHED_DTW	Salika Dhanichak Village	22.3054	87.8113	180	15.2	13
135	Simulia	Tamluk	PHED_DTW	Simulia WS scheme ; Khoridanga Village, Near Padampur 2 no GP	22.2745	87.8665	200	16.9	16.1
136	Chapbasan	Tamluk	PHED_DTW	Chapbasan PHED pump house	22.2990	87.8860	223	16.9	16.2

137	Hazalberia	Tamluk	Mk II/Pvt Tw	Hazalberia Primary School	22.2843	87.8562	150	16.05	13.95
138	Chak Srikrishnapur	Tamluk	Mk II/Pvt Tw	Nimtoiri more Smriti Soudha	22.2679	87.8938	143	16.85	12.8

5.3 Piezometric Surfaces and Ground Water Movements

The pre-monsoon water level data of the Aquifer I or Quaternary aquifer has been utilised to estimate the piezometric surface or the head with respect to the reduced level. The pre-monsoon piezometric surface varies from -4.0 to -18.0 below msl. The deeper surface is witnessed in Panskura block. Due to paucity of data of quaternary aquifer the potentiometric surface contour is developed only in few blocks in the north western parts and in the southern part of the study area (Khejuri II).The general flow gradient is not always reflected ratP a g e | **50**her the flow path is influenced by local ground water withdrawal. The heavy pumpage of irrigation tube wells in Quaternary aquifers has resulted in formation of trough in and around Panskura, thus influences the flow pattern. In Khejuri area due to insignificant



pumping in quaternary aquifer piezometric surface varies from -4 to-1 m wrt msl.

Table 5.6 Ground Water Flow in Quaternary Aquifer (Aqifer I)

The pre-monsoon piezometric water level data of the Tertiary aquifer has been utilised to prepare the piezometric contour map or the potentiometric surface of the Tertiary aquifer in the area. The piezometric surface lies between -4 to -18 below msl. The general flow from north west to south east direction. Here also, the local ground water pumpage has influenced the general flow path. Due to local development/pumping in an area and followedby comparatively lesser development in the adjacent area has resulted in the formation of ground water troughs and mounds respectively. Moderate to heavy ground water development has been witnessed around western parts of Panskura, Haldia, Sutahata, Mahisadal and Nandigram I block. However, the general flow direction in both Aquifer I and II is from NW to SE direction (Ground Water Studies in Kasai Subarnarekha Basin, CGWB, 2012)

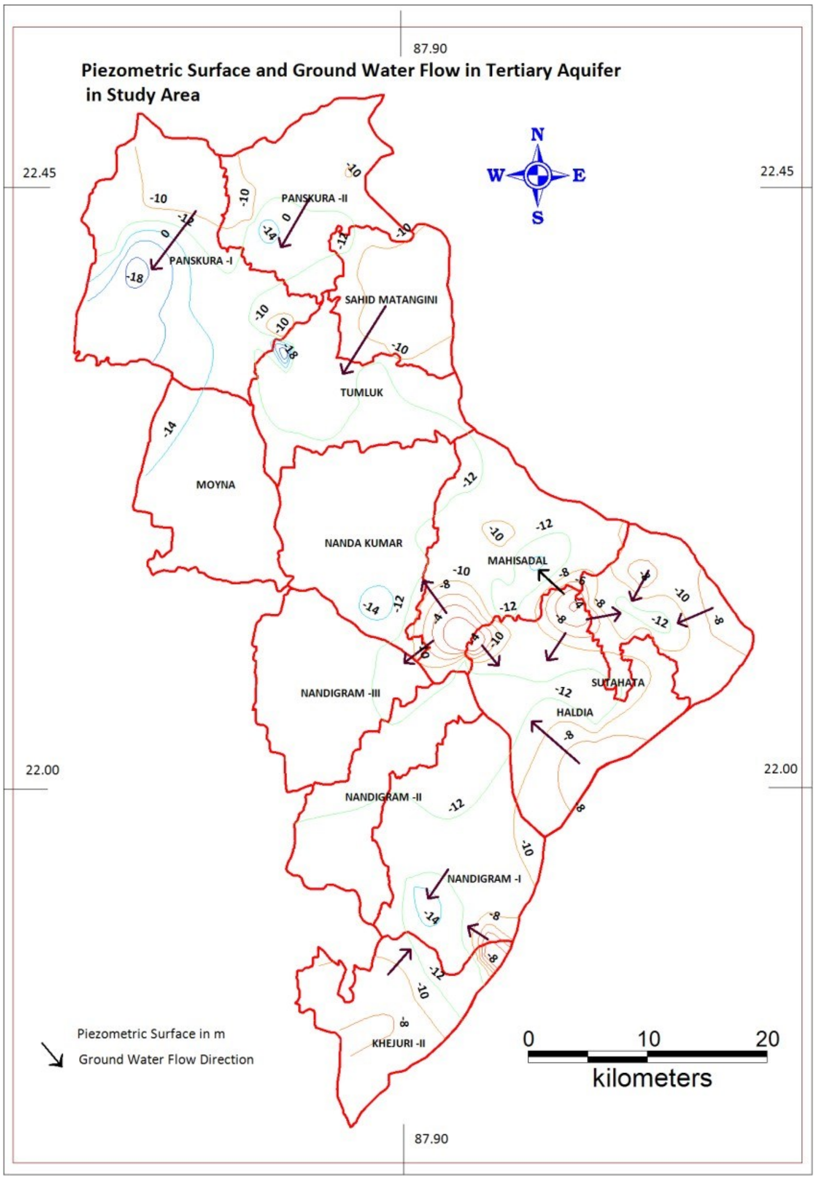


Table 5.7 Piezometric surface & Ground Water Flow in Tertiary Aquifer

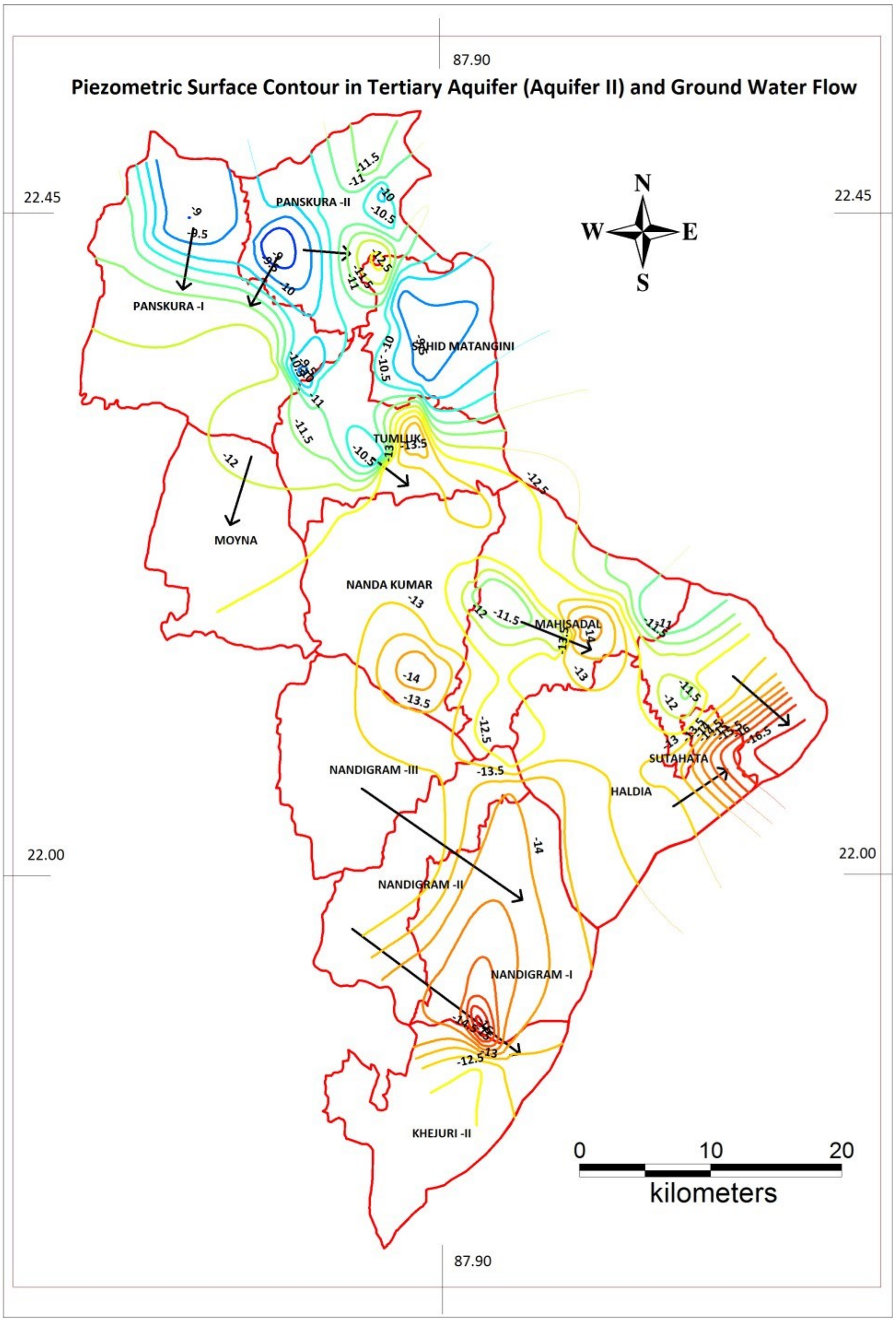


Table 5.8 General flow pattern in Tertiary aquifer (Aquifer II), NW-SE

Water table contour of shallow phreatic aquifer in Kolaghat and Panskura block lies within 6-0 m wrt msl. The water table contour is gentler around Tamluk and Sahid Matanginiblock and lies at 3 m amsl. In Khejuri II block the dune sands constitute the phreatic aquifer and water table lies at 4-6 mamsl. The flow pattern in the dune sands reflects each dune as separate hydrogeomorphic units with radial flow from top of dune towards flat lands.

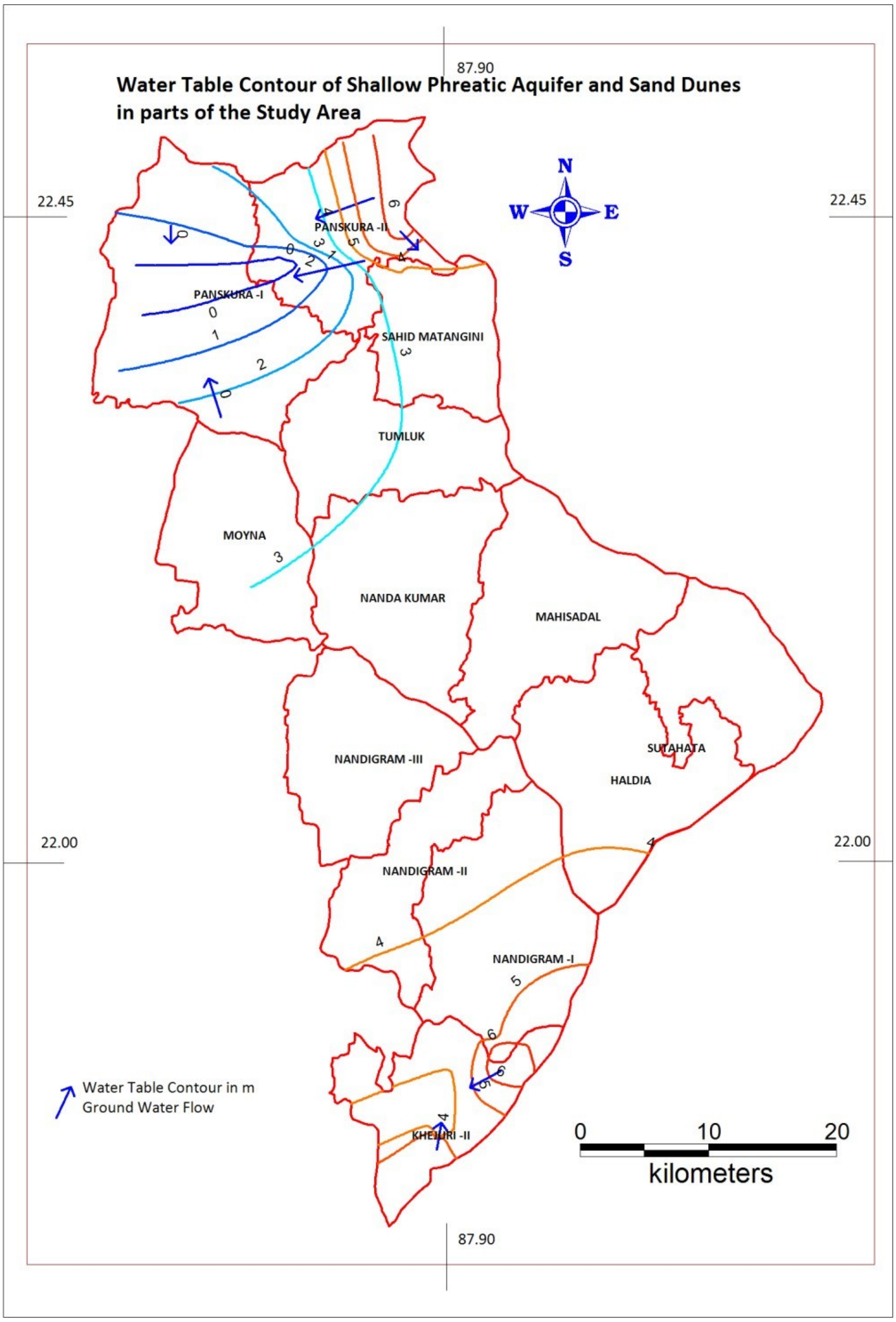


Table 5.9 Ground Water flow in Phreatic Aquifer

5.4 Long-term Water Level Trend Analysis

The historical data on water level of the observation wells of CGWB and State Water Investigation Directorate, Govt. of WB, has been analysed. The observation wells were categorized on the basis of depth. The block wise average pre and post monsoon water level for each year has been plotted to find out the long-term behavior of water level in individual aquifer in the area. The long-term water level trend of the Tertiary aquifer in the study area reveals a steady decline to the tune of 39 cm/yr to 93 cm /yr in (Khejuri II block) in pre-monsoon period and a decline of 39-50 cm/yr in post monsoon time with correlation coefficient 0.65-0.95 and 0.69-0.96 in pre and post monsoon respectively. The average water level thus has been lowered from initial level of 6-10 m in 1991/2002 to 25 m bgl. in 2017, the deepest being around Panskura block. The coefficient of determination indicates the data are representative.

Table 5.10 Long-term trend analysis of Tertiary Aquifer (Aquifer II)

Block	Year	Long-term trend (+ fall and – rise) cm/year		Coefficient of Determinations (R^2)	
		Pre-monsoon	Postmonsoon	Pre-monsoon	Postmonsoon
Panskura	1991-2017	54	44	0.75	0.87
Kolaghat	1991-2017	39	34	0.73	0.91
Tamluk	2002-2017	45	49	0.83	0.91
Sahid atangini	2002-2017	46	39	0.65	0.82
Nandakumar	2002-2017	61	53	0.89	0.95
Mahisadal	2002-2017	61	46	0.95	0.91
Sutahata	2002-2017	56	50	0.95	0.95
Haldia	2002-2017	60	52	0.91	0.97
Nandigram I	2002-2017	50	35	0.90	0.69
Nandigram II	2002-2017	64	46	0.86	0.96
Chandipur	2002-2017	73	52	0.65	0.96
Khejuri II	2002-2017	93	47	0.91	0.94

Except three inland blocks, Kolaghat, Panskura and Moyna, the long-term water level data for Aquifer II are not sufficient for regression analysis. The long-term water level trend of the Quaternary aquifer in the study area reveals a steady decline to the tune of 15 cm/yr to 59 cm /yr in pre-monsoon period and a decline of 16-44 cm/yr in postmonsoon time with correlation coefficient 0.40-0.83 and 0.71-0.90 in pre and post monsoon respectively. The correlation of time series water level data for aquifer II is moderate. The rate of decline is comparatively less in Kolaghat block, around 15 cm /yr both in pre and post monsoon time. The average water level in Panskura block is lowered from initial level 8.00 mbgl (in 1991) to 24 mbgl in 2017. Quaternary aquifer in Kolaghat block, however, witnesses least decline, from initial level of 7.50 mbgl in 1991 to 12.30 mbgl in 2017. The Moyna block also registers a steady fall.

Table 5.11 Long-term trend analysis of Quaternary Aquifer (Aquifer I)

Block	Year	Long-term trend (+ fall and – rise) cm/year		Coefficient of Determinations (R^2)	
		Pre-monsoon	Post monsoon	Pre-monsoon	Postmonsoon
Panskura	1991-2017	59	44	0.79	0.90
Kolaghat	1991-2017	15	16	0.40	0.80
Moyna	2002-2017	46	43	0.83	0.90

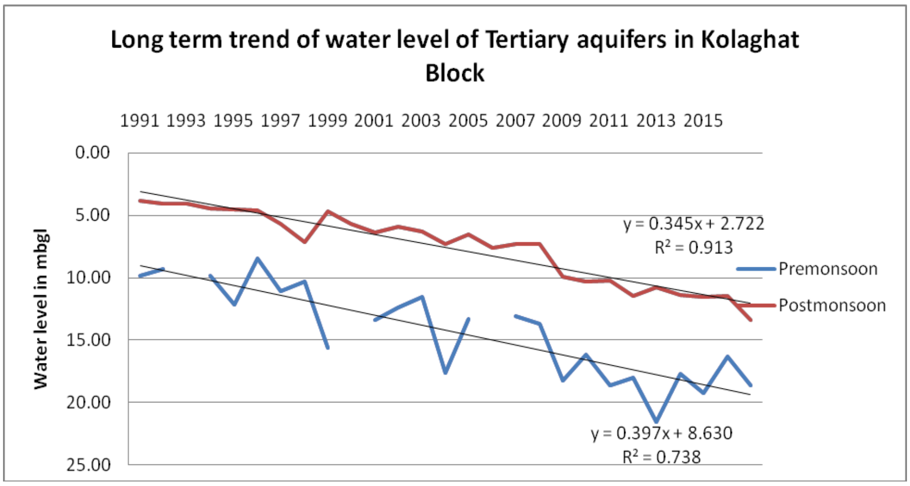


Table 5.12 Long-Term WL trend of Tertiary Aquifers in Kolaghat block

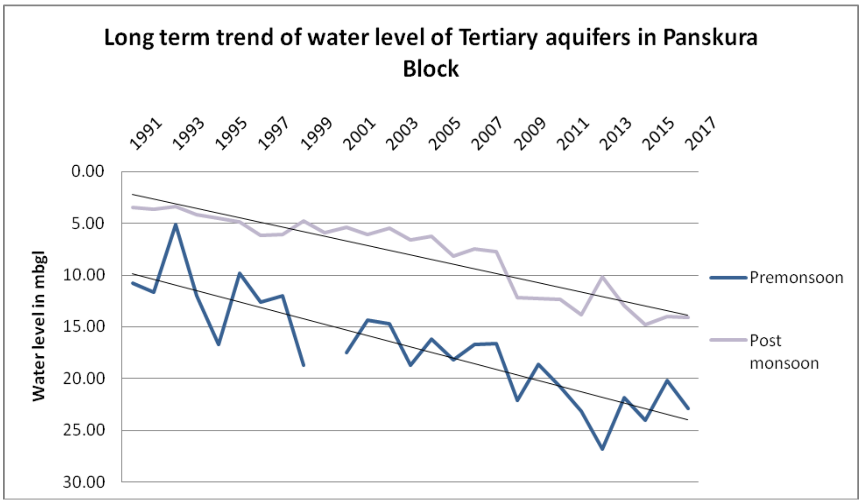


Table 5.13 Long-Term WL trend of Tertiary Aquifers in Panskura block

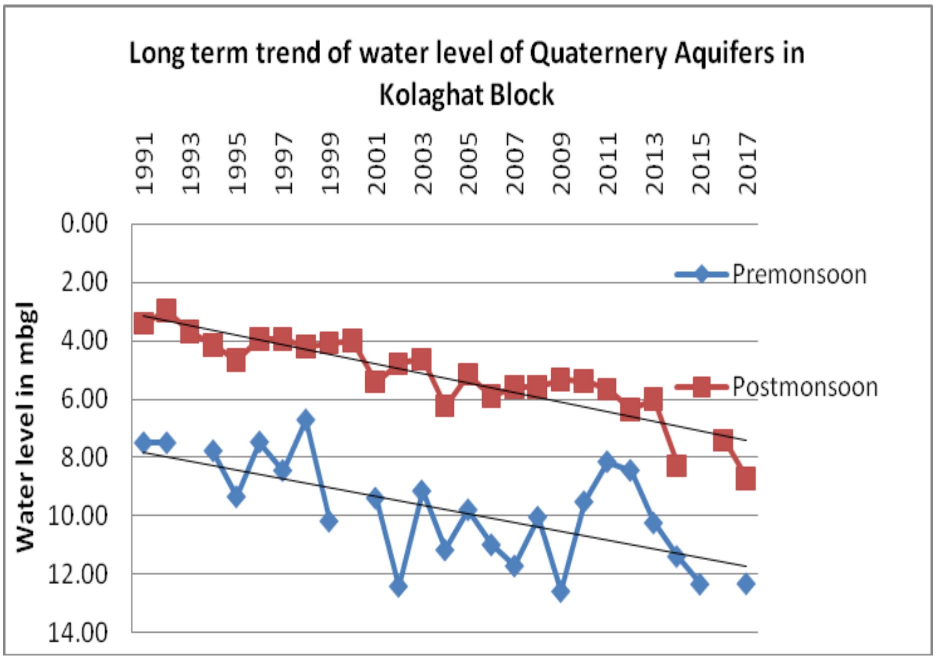


Table 5.14 Long-Term WL trend of Quarternary Aquifers in Kolaghat block

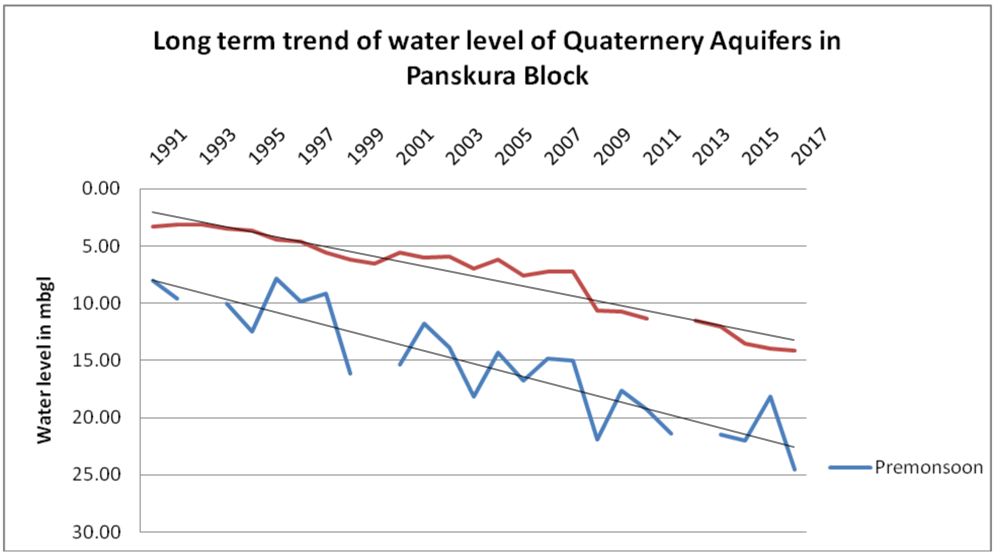


***Table** 5.15 Long-Term WL trend of Tertiary Aquifers in Panskura block*

5.5 Yield Characteristics and Potentiality of the Aquifers

Both the aquifers, Quaternary and Tertiary, are being recharged in western platform area. The older alluvium exposed in the western parts of the area plays a vital role in recharging the upper Quaternary aquifer whereas the laterite covered area further west are the potential recharge area for lower Tertiary aquifer. Both Quaternary and Tertiary aquifers are fairly potential. The wells in aquifer I or in Quaternary aquifer are the shallow, mostly private shallow tube wells within less than 100 m in inlands block only. The Government operated irrigation tube wells or drinking water tube wells are mostly positioned in the

Tertiary aquifer. The average discharge of the shallow tube wells in Quaternary aquifer is 30-50 m^3/hr. Recent exploration of CGWB at Khejuri II block observed discharge of 50 m^3/hr in shallow exploratory well of 111 m depth tapping 9 m aquifer zone within 82-108 m depth in Quaternary aquifer.

Throughout the study area, the irrigation tube wells of Agra Irrigation Department, Govt. of West Bengal and also the drinking water tube wells of PHED, Got of West Bengal are by and large tapping the Tertiary aquifers only. The table 13 shows that the yield characteristics and aquifer parameters of Tertiary aquifer (aquiferII). Yield of the Aquifer II is 30-180 m^3/hr (Fig.38). The higher discharges are observed around Panskura, Kolaghat, Sahid Matangini, Tamluk block. The discharge in the coastal area, around Haldia, Sutahata, Khejuri, Nandigram I etc. Is also high to the extent of 60- 120 m3/hr. Drawdown is moderate 3-6 m. Recent exploration of CGWB at Kasaria, in Khejuri II block reveals that deep tube well of 245 m depth tapping 21 m granular zone yield at 108 m^3/hr and deep tube wells of 267 m depth at Maheshpur, Nandigram I block, tapping 30 m granular zone within 220-265 yield at 66 m^3/hr. The specific capacity varies from 7.89-75 m^3/hr/m (fig 39). High discharge and less drawdown in the north and north western parts of the study area resulted higher specific capacity. In major part of the study area, from north to south the specific capacity ranges between 20-35 m^3/hr/ m. Less specific capacity 5-20 m^3/hr/ m is observed in Haldia, Sutahata in the south eastern part and in few pockets in north western part of the study area in Panskura etc. The specific capacity is higher than the average around Sahid Matangini, and in few pockets of Tamluk area and ranges between 35-50 m^3/hr/ m. Variation of specific capacity in north south and east west section is depicted in Table 5.19 & Table 5.20. The transmissivity of Aquifer II is very high, and average being considered as around 2000 m^2/day and storativity in the range of $3X10^{-4}$-$5.465X10^{-4}$.

Table 5.16 Yield and Aquifer Potential of Tertiary Aquifer

Name	Block	Total Depth in m	Zones tapped (in m)	Discharge (m^3/hr)	SWL mbgl	DD in m	Sp Capacity (m3/hr/m)	Transmi-ssivity (m^2/day)	Storativity
Kulbari WSS	Chandipur	274.50		85.24	9.77	2.98	28.60		
Erashal	Chandipur	301.5		138.65	4.11	5.99	23.15		
Kotbar	Chandipur	256.00		50	18.8	3.57	14.01		
Barbasudevpur	Sutahata	282.85	247-277	108	8.53	5.48	19.71		
Dwariberiya	Haldia	301.22	248-278	124	7.39	5.49	22.59		
Bore hole IOC	Haldia	304.80		90				788	
Haldia helipad	Haldia	228	180-194,220-225	90				789	
Monoharpur	Sutahata	310.31	266-291	88	8.03	5.67	15.52		
Chaitanyapur	Sutahata	332.00	240-252,264-282	141	8.5	3.35	42.09		
Tabakhali WSS	Sutahata	300.53	248-278	56	15.75	4.46	12.56		
Barmohanpur	Sutahata	296	258-268						
Haldia Anc Camp	Haldia	300.00	155-160,164-170,177-182,203-224	65		4.7	13.83		
Dhenkua	Sutahata	228.65	185-201	57	7.5	5.7	10.00		
Kukrahati	Sutahata	211	194-200		7.1				
Khejuri Well field	Khejuri II	350.00	234-291	111		4.92	22.56	2400-2800	**$3X10^{-4}$**
Kamarda	Khejuri I	291.00	190-197						
Khejuri Primary school	Khejuri II	282.00	180-186						
Kasaria high school	Khejuri II	290	221-242	108	14				
Kasaria high school	Khejuri II	111	82-91 105-108	50	8.00				
Mecheda WSS	Kolaghat	210.10	158-188	140	14.18	3.25	43.08		
Rain WSS	Kolaghat	280.00	182-209	68	10	5.64	12.06		
Asurali WSS	Kolaghat	190.10	145-178	138	6.48	3.05	45.25		
Gopalnagar WSS	Kolaghat	201.2	134-152,163-175	48	7.5	2.7	17.78		
Paschim Manika	Kolaghat	186	140-157,164-178	164	7.49	5.6	29.29		
Brindabanchak	Kolaghat	170.8	75-150						
Rangibasan	Mahisadal	299.70	231-262	125	8.31	4.88	25.61		
Kapasariya	Mahisadal	300.00		72	8.83	3.36	21.43	337	**$4.9X10^{-5}$**
Kesabpur Jalpai	Mahisadal	210.00	192-198		5.5				
Ajra	Mahisadal	210	194.5-200.5		7.15				

Natsal	Mahisadal	210	164-170		6.68				
Basulia	Mahisadal	296	228-234						
Namalakha	Mahisadal	292	241-271	79	17.38	5.29	14.93		
Moyna WSS	Moyna	301.35		125	9.15	4.55	27.47		
Paramanandapur	Moyna	200.30		111.37	7.9	5.2	21.42		
Bolaipanda	Moyna	200.30							
Khejurberia	Nandakumar	250.00	188-218,222-270	72	14.5	5.36	13.43		
Norghat	Nandakumar	250.00			19.3				
Thenkuachak	Nandakumar	215.00	165-196	118	10.36	4.25	27.76		
Dakhin Gumai	Nandakumar	253.83	176-201	140	7.31	3.96	35.35		
Bargoda	Nandakumar	260.45	160-182,188-206	111	6.85	2.28	48.68		
Sitalpur Jalpai	Nandakumar	231.5	129-156	111	3.2	5.33	20.83		
Nandakumar	Nandakumar	210	196-202		6.47				
Tajpur WSS	Nandigram I	292.16							
Maheshpur EW	Nandigram I	267	219-231, 235-247, 258-264	66					
Reyapara WSS	Nandigram I	234.00							
Gholpukuria	Nandigram II	282.00							
Nandigram Hospital	Nandigram I	266.00							
Sonachura WSS	Nandigram I	282.00							
Gogras Keshab Bar	Panskura	230.00	162-193	67	20.5	5.2	12.88		
Uttar Mechogram	Panskura	201.17	148-154,164-188						
Dokanda	Panskura	201.17		122.75		4.89	25.10		
Joykrishnapur	Panskura	200	134-174						
Harirampur	Panskura	202.69	113-145						
Khandakhola	Panskura	201.78	127-157						
Fakirganj	Panskura	202.56	155-185						
Gotpota	Panskura	200	110-140						
Ratulia	Panskura	250.07	68-74,82-88,122-128	30	9.4	3.8	7.89	983	**$4X10^{-4}$**
Gumai	Panskura	215	140-158,176-182,200-212	65	7.73	4.97	13.08	2659	**$5.465X10^{-4}$**
Burari Hat	Sahid Matangini	252.00	170-176						
Ramtarak	Tamluk	210.00	179-185		9.7				
Santipur	Sahid Matangini	182	142-172	220	2	6	36.67		

Mahisda	Sahid Matangini	225	166-191	177	8.35	4.07	43.49		
Kakurkhana	Tamluk	160.00	112-130,134-140	230	2	3.048	75.46		
Malahait	Tamluk	258.00	162-168		6				
Anantapur	Tamluk	260.00	145-175	126	6	2.15	58.60		
Simulia	Tamluk	213.21	167-197	165	9.75	4.88	33.81		
Chapbasan	Tamluk	235.5	185-219	125	8.38	5.42	23.06		
Ratulia Dolbar	Panskura			84	23.62	7.62	11.02		

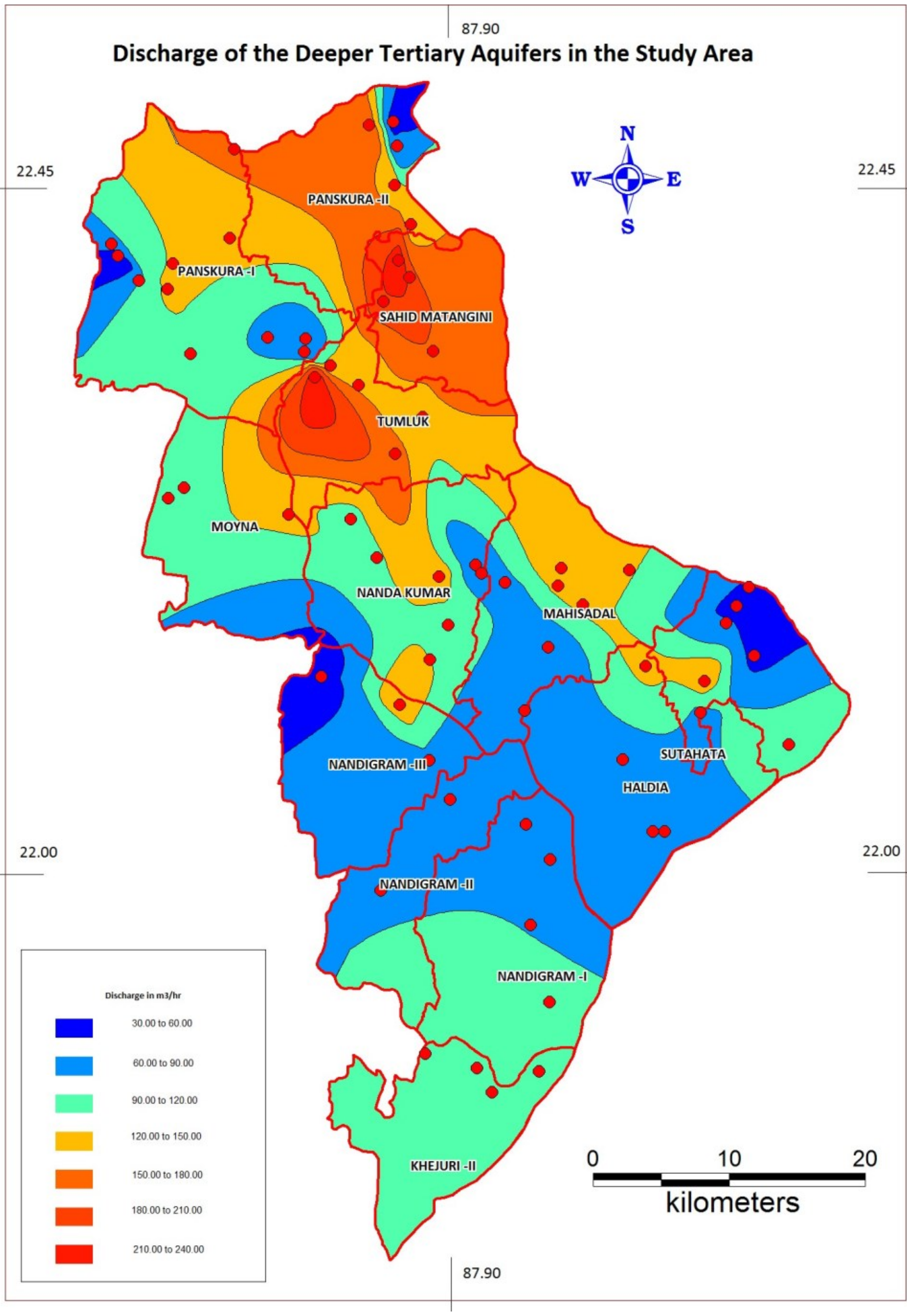


Table 5.17 Yield Map of Tertiary Aquifer (Aquifer II)

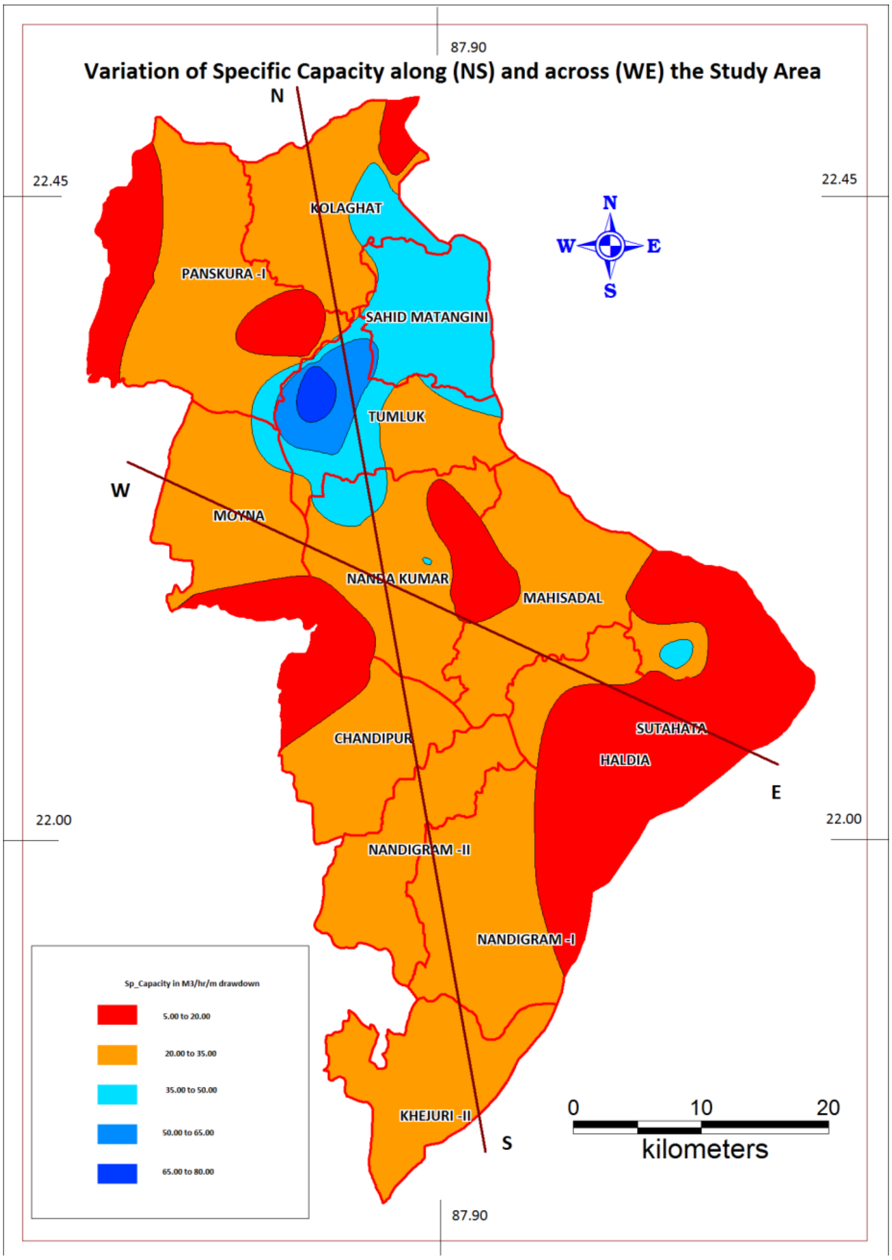


Table 5.18 Specific Capacity Map of the study area

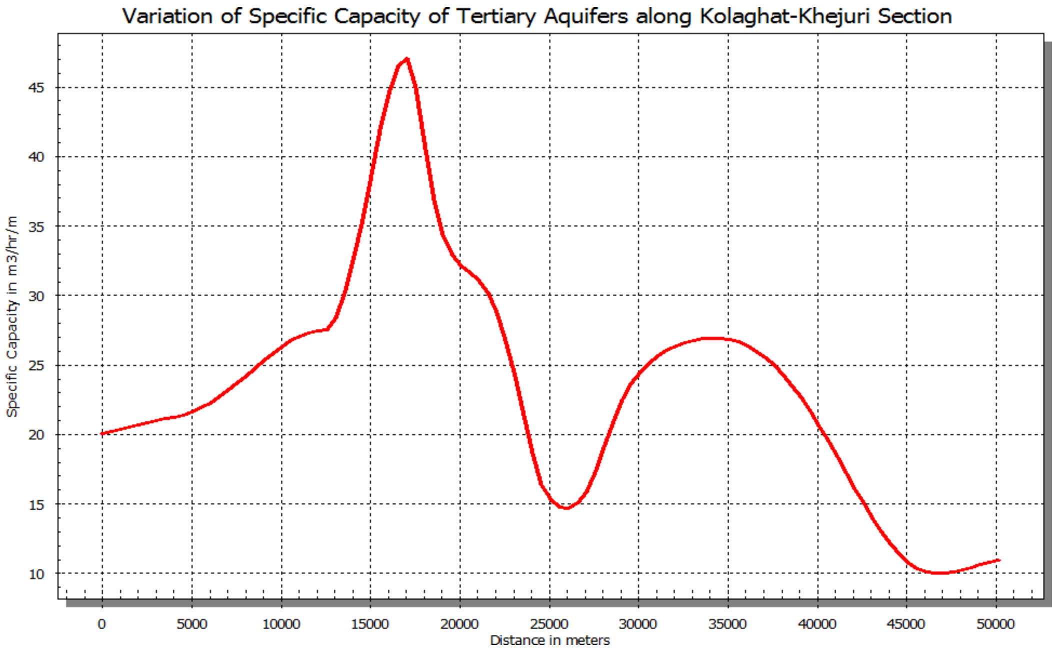


Table 5.19 Variation of Specific Capacity of Tertiary Aquifers along Kolaghat-Khejuri Section

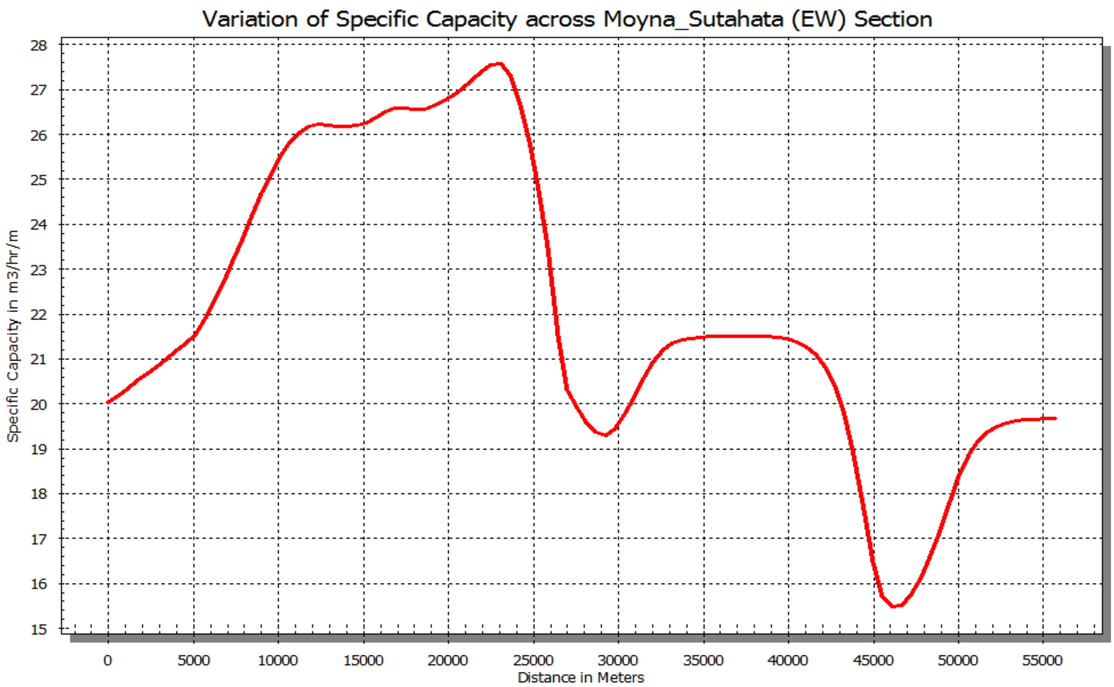


Table 5.20Variation of Specific Capacity of Tertiary Aquifers along Moyna-Sutahata section

6.0 GROUND WATER RESOURCES

6.1 In-storage Ground Water Resources

From the lithological disposition in the area, it is understood that both the Aquifer I (Quaternary) and the Aquifer II (Tertiary) is under semi confined to confined condition. The unconfined aquifer is found only in discontinuous patches and generally not developed extensively. Therefore, dynamic ground water resource in the area by direct rainfall recharge is insignificant and thus not assessed except for dune area. The available resource in semi confined and confined aquifer has been assessed by storage concept, the resource under pressure is only considered as the ground water potential. The quantity of water released in confined aquifer due to change in pressure can be computed between pre-monsoon piezometric head (h_t) at any given time 't' and the bottom of the top confining layer (h_o) by using the following equation.

$Q_P = SA\Delta h = SA (h_t - h_0)$, S = storativity/storage coefficient

Assessment of ground water resources of confined aquifers assumes crucial importance, since over-exploitation of these aquifers may lead to far more detrimental consequences than to those of shallow unconfined aquifers. If the piezometric surface of the confined aquifer is lowered below the upper confining layer so that desaturation of the aquifer occurs, the coefficient of storage is no longer related to the elasticity of the aquifer but to its specific yield. In view of the small amounts of water released from storage in the confined aquifers, large scale pumpage from confined aquifers may cause decline in piezometric levels amounting to over a hundred metre and subsidence of land surface posing serious geotechnical problems.

As per the recommendation of GEC, 2015, ground water storage approach is applied to assess the ground water resources of the confined aquifers. The co-efficient of storage or storability of an aquifer is defined as the volume of water it releases or takes into storage per unit surface area of the aquifer per unit change in head. Hence the quantity of water added to or released from the aquifer (ΔV) can be calculated as follows

$\Delta V = S\ \Delta h$

If the areal extent of the confined aquifer is A, then the total quantity of water added to or released from the entire aquifer is

$Q = A$

$\Delta V = SA \Delta h$

Where

Q = Quantity of water confined aquifer can release (m^3)S = Stativity

A = Areal extent of the confined aquifer (m^2)

Δh= Change in Piezometric head (m)

GEC, 2015 says, “If any development activity is started in the confined aquifer, then there is a needto assess the dynamic as well as in storage resources of the confined aquifer. To assess the ground water resources of the confined aquifer, there is a need to have sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is also needed”. Here, both the aquifers are developed extensively for irrigation and drinking water needs since long. But it is observed that, the study area, being a part or very adjacent to the coastal area, the piezometric surface of both pre and post monsoon lies below the sea level. Therefore, following the recommendation of GEC, 2015, the dynamic component of resource in Aquifers I and II are considered as zero.

For assessing the in-storage ground water potential of the confined aquifer, the resources between the pre monsoon piezometric head of that particular aquifer and bottom of the top confining layer are computed. That can be assessed using the following formula:

$Q_I = SA\Delta h = SA (h_{PRE} – h_0)$

Where

Q_I = In-storage Ground Water Resource of Confined Aquifer (m^3)S= Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

h_0 = Bottom level of the top confining layer (m amsl)

HPRE = Piezometric head during pre-monsoon period (m amsl)

Resource has been assessed for Tertiary Aquifer separately for each block in the entire area. The bottom of the Tertiary clay at the particular block is considered as h_0. Considering limited number of working ground water structures in Quaternary Aquifers (Aquifer I), water level/ piezometric surface data is available for Kolaghat, Panskura, Sahid Matangini, Moyna and Khejuri II blocks. Resource assessment of Quaternary part of confined aquifers is restricted to these blocks only. For Quaternary aquifer resource, the bottom of the clay overlying the Q2 aquifer, or the older alluvium is considered as h_0.

The Total Resource in the study area by storage concept in Tertiary Aquifer 139.4285 MCM, Table 6.1.

Total Resource in Quaternary Aquifers (Kolaghat, Panskura, Moyna, Sahid Matangini and Khejuri II Blocks) is 12.0390 MCM, Table 6.2.

The present ground water draft in the area is for drinking and industrial uses and for irrigation purposes. The drinking water wells is mostly from the deep tube wells of PHED, water supply schemes and other hand pumps and Mark II tube wells. At present 47% of the total population in the district has been brought under coverage of water supply schemes of PHED and rest is achieved from spot sources. The drinking water tube wells in the study area are mainly in the Tertiary aquifer (Aquifer II). The irrigation tube wells of Agri Irrigation department, Govt of West Bengal are mostly deep tube wells with depth more than 100 m. Shallow tube wells for irrigation uses are private owned. Deep and shallow tube wells are concentrated in inland blocks Kolaghat, Panskura and Moyna block. However, Tamluk, Nandakumar, Chandipur and Khejuri II block are found to have few shallow or deep tube wells. The other coastal blocks do not have irrigation tube wells.

Table 6.1 In-Storage Ground Water Resources of Tertiary Aquifers (by Storage Concepts) in the Study Area

Block	Area in sq km	Average Storativity	Pre-monsoon Piezometric surface of Tertiary aquifer (m)	Depth (in m) of bottom Confinning layer (Q/T Clay)	Δh = Difference between piezometric surface and bottom of confining layer	Resource/Available Storage in MCM
Kolaghat	145.79	0.000356	17.8	103	85.2	4.4220
Panskura	227.14	0.000356	22	97	75	6.0646
Panskura Municipality	19.94	0.000356	22	97	75	0.5324
Moyna	158.69	0.000356	17	160	143	8.0786
Sahid Matangini	97.82	0.000356	16.5	120	103.5	3.6043
Tamluk	113.07	0.000356	17	105	88	3.5423
Tamluk Municipality	17.86	0.000356	17	105	88	0.5595
Nandakumar	165.7	0.00068	18.4	117	98.6	11.1099
Mahisadal	146.48	0.00068	17	130	113	11.2555
Chandipur	137.58	0.00068	18.8	114	95.2	8.9064
Nandigram I	181.84	0.00068	16	190	174	21.5153
Nandigram II	105.74	0.00068	18.3	190	171.7	12.3458
Khejuri II	137.46	0.00068	16	215	199	18.6011
Haldia	65.44	0.00068	16.3	183	166.7	7.4180
Sutahata	79.54	0.00068	15.8	183	167.2	9.0434
Haldia Municipality	109.65	0.00068	16.3	183	166.7	12.4295
					Total	139.4285

Table 6.2 In-Storage Ground Water Resources of Quaternary Aquifers (by Storage Concepts) in the Study Area

Block	Area insq km	Average Storativity	Pre-monsoon Piezometric surface of Quaternary Aquifer (m)	Depth (in m) of bottom Confinning layer of Quaternary aquifer(Q2)	Δh = Difference between piezometric surface and bottom of confining layer	Resource/Available Storage in MCM
Kolaghat	145.79	0.000356	12	68	56	2.9065
Panskura	227.14	0.000356	22.5	57	34.5	2.7897
Panskura Municipality	19.94	0.000356	22.5	57	34.5	0.2449
Moyna	158.69	0.000356	17.35	75	45	2.5422
Sahid Matangini	97.82	0.000356	15.25	68.75	35	1.2188
Khejuri II	137.46	0.00068	10	35	25	2.3368

6.2 Ground water flow through the Tertiary aquifer (Aquifer II)

The ground water in the coastal as well as in the inland blocks in the study area occurs under semi confined to confined condition in Aquifer I and II and is recharged from the western parts of marginal sedimentary area. The exact recharge to these aquifers through the unconfined part is always difficult to assess. From the piezometric contour map in the study area the average gradient of flow has been determined and maximum flow path has been confirmed for each block. The average transmissivity is considered as 2000 m2/day. These data are utilized to determine the quantum of subsurface flow through the deeper confined Tertiary aquifer (Aquifer II). It is assessed that 48.73 MCM of ground water Table 6.3 is flowing through the Tertiary aquifer in the study area and the general gradient flow is from NW-SE.

Table 6.3 Estimation of Flow in Tertiary Aquifer Applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in ($m^{2/}$day)	Annual Flow in MCM
Kolaghat	16.67	0.000388	2000.00	4.72
Panskura	20.67	0.000386	2000.00	5.83
Sahid Matangini	10.67	0.000300	2000.00	2.34
Tamluk	15.67	0.000368	2000.00	4.21
Moyna	12.00	0.000060	2000.00	0.53
Nandakumar	16.67	0.000265	2000.00	3.23
Khejuri II	20.00	0.000250	2000.00	3.65
Nandigram I	14.33	0.000300	2000.00	3.14
Nandigram II	20.67	0.000300	2000.00	4.53
Chandipur	15.00	0.000300	2000.00	3.29
Haldia	15.00	0.000500	2000.00	5.48
Sutahata	11.67	0.000563	2000.00	4.79
Mahisadal	18.33	0.000225	2000.00	3.01
	Total			**48.73**

6.3 Resource in Dune Sands in Khejuri II blocks

In Khejuri II block, elongated arcs of sub parallel sand ridges are found to occur separated from one another by low lying agricultural fields. These elongated and elevated sand bodies are situated within 20 km of present shoreline, earlier described as "beach ridges" by Niyogi (1970). Nearly uniform orientation of notch shaped dunes along the coast indicates a steady and uniform wind direction. The dunes are characterized by dense vegetation. 4 major dunes are identified in Khejuri II blocks. Maximum elevation of dune ridges 10-12 m amsl. The sands are fine grained with moderate to high infiltration capacity. Each dune serves as separate hydrogeomorphic units with maximum dimension is 5 km X 2 km. Nijkasba dune along the coast in the southern part of Khejuri II Block is the largest. The Khejuri dune, itself hosts the Khejuri village is about 2 sq. km. Total area under dune sands is 6.6364 sq km. The dunes are highly potential, yield 0.66 to 6 m3/hr, drawdown within 2 m. The pre-monsoon static water level varies from 2.5-7.4 mbgl. In post monsoon time it rests within 1-3.25 mbgl. The larger the dune area better is potentiality and sustainability against pumping.

Although the Ec value of the water from the dune aquifer is within permissible limit, the water from dune is not utilized for drinking uses and very limited uses for domestic purpose has also reported. The chemical analysis report from dune aquifer in Khejuri II block reveals that the water is potable with Ec within 2000 µs/cm. At present utilization of dune sand aquifer is negligible.

The total rainfall resource available has been assessed by Rainfall Infiltration Factor method with RIF as 25% and considering normal monsoon rainfall 1.3643 m. The natural discharge is taken as 10%. Recharge due to non-monsoon rainfall is negligible.

Therefore, the total available annual resource from dune sands is estimated as 2.04 MCM.

7.0 HYDROCHEMISTRY

Ground water samples were collected from the observation wells in the study area for chemical analysis. Keeping in mind the probable brackish nature of the ground water in near coastal area spot measurement of electrical conductivity were recorded. Considering, the disposition of aquifer system in the area target was set to collect representative samples from Aquifer I or the Quaternary aquifer, Aquifer II or the Tertiary aquifer and Phreatic aquifer of dug wells or dune sandsin Khejuri II block.

The analysis of basic parameters along with pH and EC of ground water samples reveals that, there are not much specific variation of ground water quality from different aquifer sources. The water is generally fresh and, in few cases, faintly brackish. It is assumed that the water in deeper Tertiary (aquifer II) zone is mostly fresh and water from Quaternary (aquifer I) is comparatively brackish or saline. Salinity in the ground water is normally classified based on its taste (palatable or unpalatable), total dissolved solids, electrical conductivity or EC and chloride content. Conventionally ground water is categorized as below:

EC µS/cm at 25 ° C	Category
<1600	Fresh
1600-5000	Slightly saline or brackish
5000-15000	Moderately saline to saline
15000-50000	Very saline
>50000	Brine

For the present study electrical conductivity up to 2000 µS/cm has been considered as the upper limiting value for fresh water.

However, truly saline water is rare in occurrence because of natural dilution and baseexchange process in the aquifer. The wells are generally non-existent, not in use or not in working condition in the brackish to saline upper aquifer (Aquifer I) in the coastal blocks. Therefore, scope for direct sampling of brackish water in the coastal area is very limited. The extent of the study of chemical quality, thus, restricted to the Quaternary aquifers in inland blocks, where the Quaternary aquifers (aquifer I) is fresh. In case of coastal blocks, the study is limited to the deeper Tertiary freshwater aquifer (aquifer II) due to paucity of systematic chemical data from Aquifer I. Occurrence of moderately saline to saline water (>7000 µS/cm), in rare incidence, in otherwise fresh Tertiary aquifer indicates the leakage in the affected tube well. This indirectly hint towards the salinity of the upper aquifer in the area, i.e., few Tara pump in Kastala village in Khejuri II block, Solat WSS of PHED in Haldia block etc. Reporting of morning salinity in few tube wells of PHED at Aquifer II in Mahisadal block also suggest for brackish to saline nature of Aquifer I. Number of tube wells constructed for irrigation uses in few of the coastal blocks has been reported as defunct for saline water pumping.

The Table 7.6 narrates the chemical quality mostly from Tertiary aquifer. It is slightly alkaline in nature with pH in the range 7.19 to 8.50, with median value at 7.94. The EC value ranges between 452-3742 µS/cm with average around 1200 µS/cm. The lower EC, less than 500 µS/cm has been recorded from Tertiary aquifer in Panskura, Moyna etc and in dune sands in Khejuri. The chloride content varies between 15-650 mg/l, with median at 150 and standard deviation 140. Therefore, more or less the chloride is within permissible limit for drinking except few occasions. Na has reported higher side, average around 170 mg/l. Ca and Mg is moderate and mostly within permissible limit. HCO_3 ranges between 40-760 mg/lit, average > 250 mg/lit. SO_4, NO_3, PO_4 are mostly within the permissible limit with few exceptions. It is understood from Fig. 41a, that the Ec and chloride is very well correlated with coefficient of determination around 0.78. The correlation between sodium and chloride (fig.41b) is moderate around 0.50. However, overall correlation of sodium with SO_4 is poor. The degree of mineralization and the content of chloride generally increase towards the coast than the inland blocks, the Fig.42, shows that the variation in content of chloride as we move from inland blocks towards the coastal blocks. The electrical conductivity of ground water from Tertiary aquifer indicates the Tertiary aquifer in inland blocks are fresh within 500-1000 µS/cm and in rest of the area slightly brackish with EC 1000-1500 µS/cm. The higher EC values more than 2000 µS/cm, in Tertiary is reported in isolated pockets only in Haldia Sutahata and in Nandakumar block (Fig.43). The content of Fe more than permissible limit is found in number of occasions in Tertiary aquifer, maximum concentration reported as 10.53 mg/lit, with mean around 2.1 mg/lit and standard deviation is 2.78. Both the samples from quaternary aquifer, at Siddha Hand

Pump in Kolaghat and at Haldia reported high concentration of Fe. Therefore, Fe in ground water more than the permissible limit may be acknowledged as general problem in the study area.

The quality of water from dune sands in Khejuri II block is also matter of concern as the dune water may serves as the alternate effective source of drinking and irrigation in otherwise fresh water deficient area. The dune water within 10-20 m depth is mostly fresh with EC ranges between 470- 1641 µS/cm. Occurrence of high EC value of 2700 µS/cm at Paduvery village in Nijkasba dune may be due to entrapped salinity and less flushing. The electrical conductivity map of ground water from dug wells and dune sands (Table 7.4) exhibits that the dug well zones and the dune aquifer is mostly fresh or faintly brackish with EC <2000 µS/cm. The Fe content in dune sands is below 1 mg/lit. In Khejuri Dune water the SO4 is high as 375 mg/lit, the higher SO4 is associated with high Na content, also. PO4 is also sometime higher. The higher sulphate in very shallow dune may be anthropogenic due to leakage of sewer, less flushing or use of ammonium sulphate as fertilizer etc. However, it is not well correlated with NO3. The increase in PO4 in dune water may also be due to use of phosphate base fertilizer. The anthropogenic influences on dune water may further required to be investigated and necessary remedial measures may be adopted to make the fresh water from dune sands potable or palatable. The piper diagram or trilinear diagram (Table 7.5) is a tool to represent the relative abundance of common ion in a set of samples. The plot of the water samples reveals that the water samples are sodium chloride and sodium bicarbonate water. The Wilcox shows that majority falls in the zone C3S2, high salinity and medium sodium hazards whereas few samples show C2S1 and C1S1, medium salinity and low sodium hazard zone.

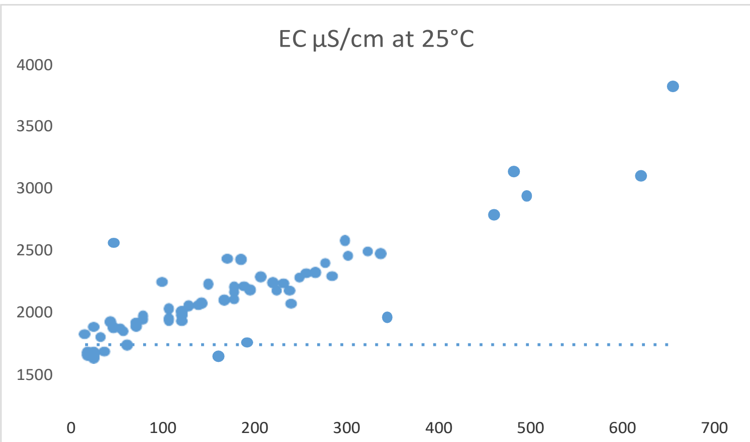


Table 7.1 EC vs. Chloride content in ground water in the study area

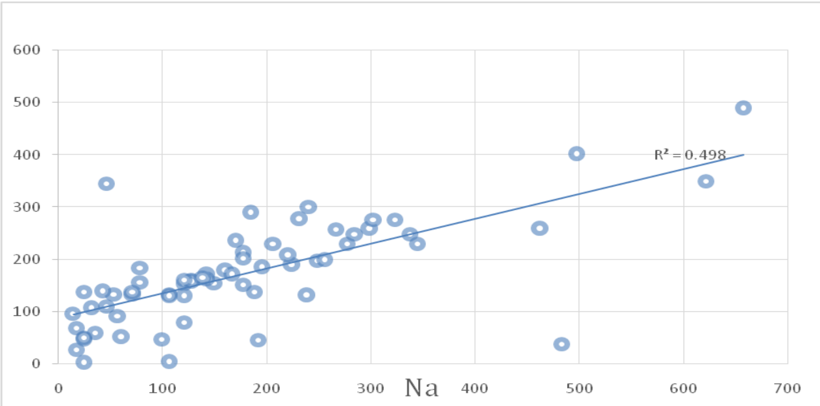


Table 7.2 Na vs. Chloride content in ground water in the study area

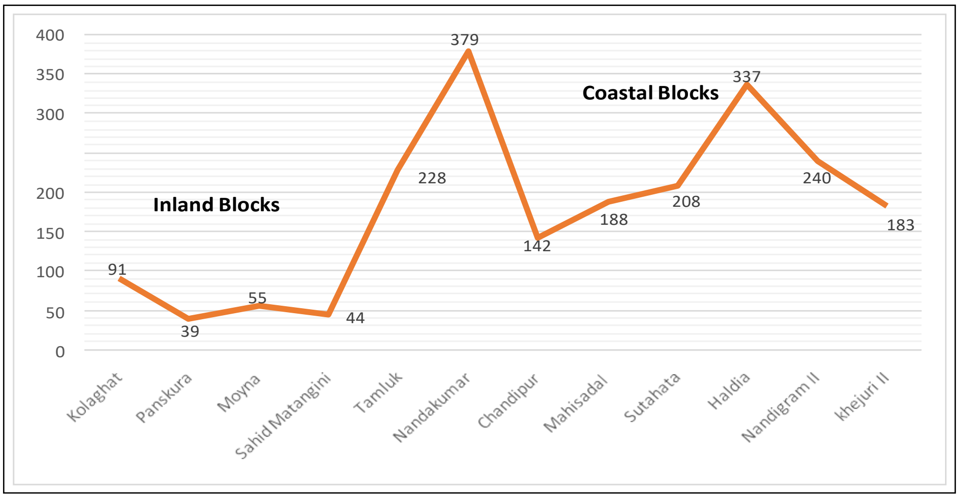
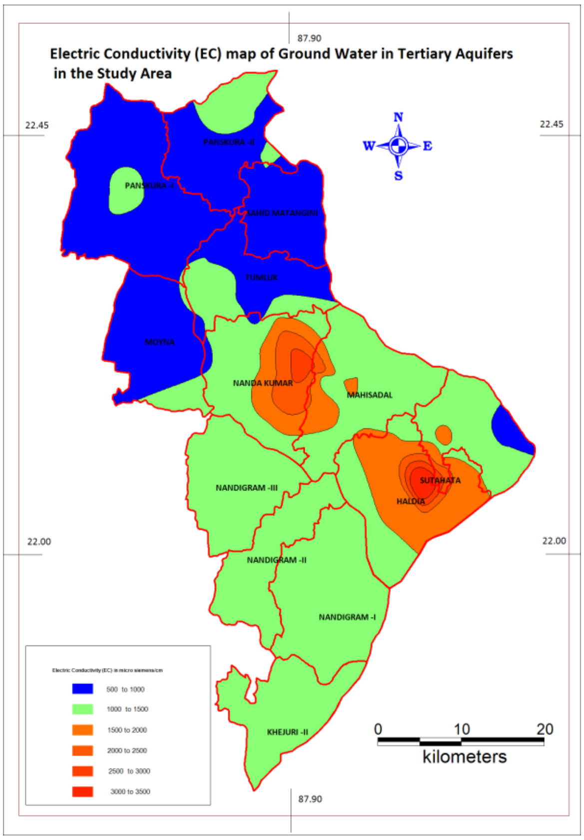


Table 7.3 Block wise average concentration of Chloride in mg/lit



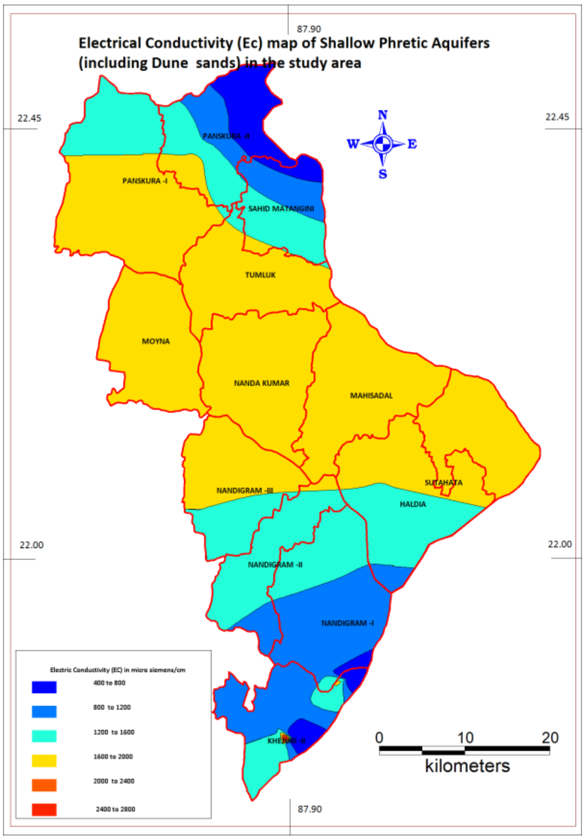


Table 7.4 EC of Tertiary and Shallow Phreatic aquifers

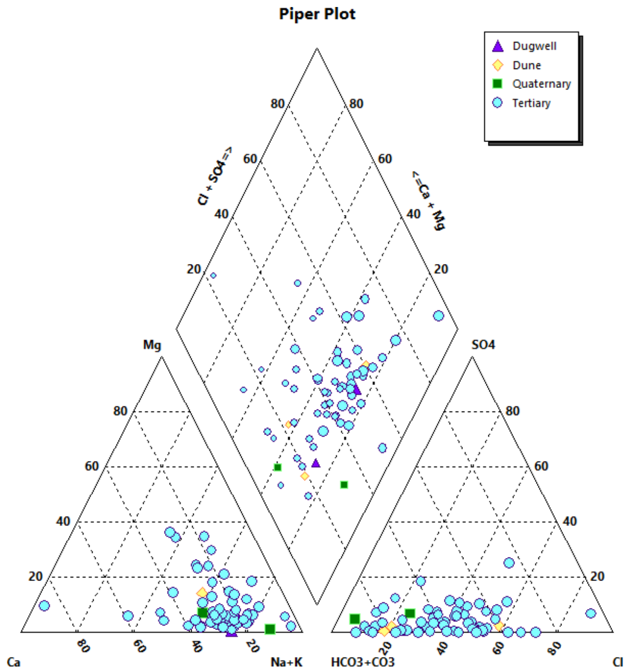


Table 7.5 Piper and Wilcox plot of water samples

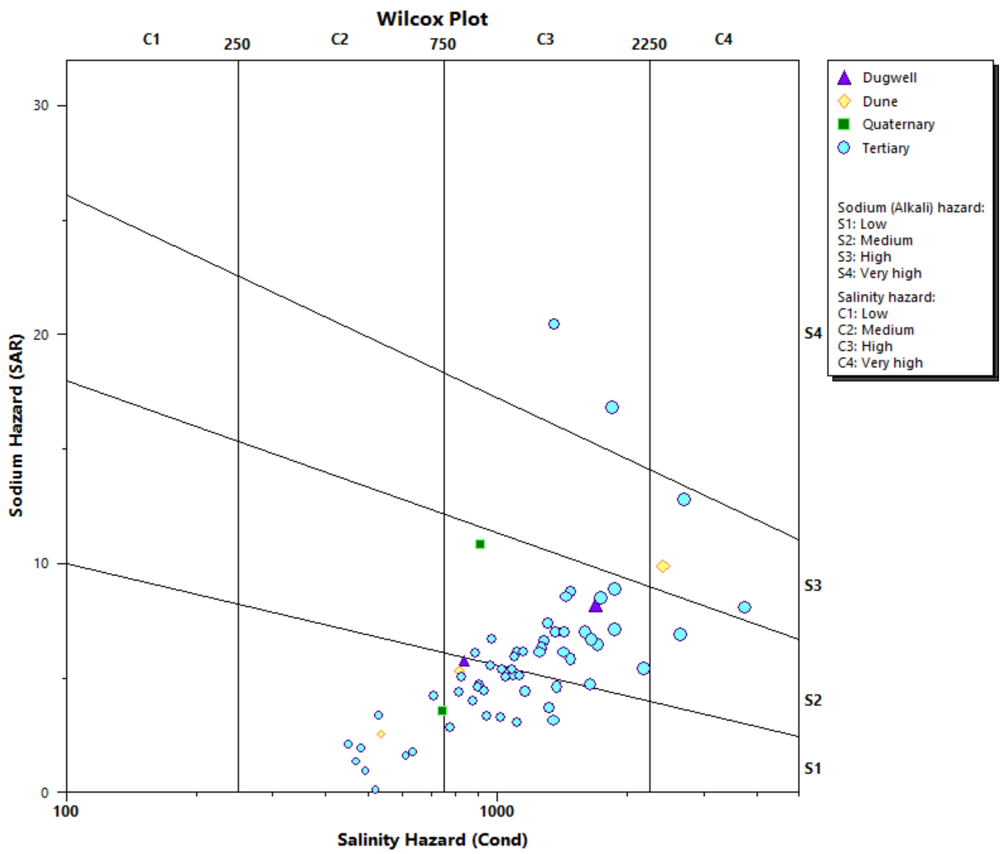


Table 7.6 Chemical Quality of ground water samples from the observation wells in Study area

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO3	HCO3	TA as CaCO3	Cl	SO4	NO3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO4	Fe
1	Muradpur	Chandipur	Tertiary	8.15	1161	bdl	329	270	178	52	15	50	9	225	152	23.4	0	2.25
2	Ersal	Chandipur	Tertiary	8.24	1111	bdl	378	310	142	14	21	38	2	150	173	15.6	0	0.27
3	Rasikchak	Chandipur	Tertiary	7.8	1021	bdl	67	372.1	121	16	9.5	54	5	155	154	8	1.7	bdl
4	Kotbar	Chandipur	Tertiary	7.92	1078	bdl	250	372.1	128	32	22	54	9	170	161	12	1.9	bdl
5	Haldia Township	Haldia	Quaternary	7.82	1710	bdl	409	335	338	38	10	6	2	280	248	50.7	1.6	9.14
6	Barsunda	Haldia	Tertiary	7.63	1597	bdl	122	384.3	277	55	42	44	23	205	230	70	0	bdl
7	Solat	Haldia	Tertiary	8.16	3742	bdl	275	1091.9	658	22	18	266	9	700	490	101	6.3	0.33
8	Mohonpur	Haldia	Tertiary	8.17	1424	bdl	214	384.3	249	11	6.3	66	9	200	198	43	9.1	4.31
9	Dwariberia	Haldia	Tertiary	7.94	1308	bdl	61	463.6	178	16	10	56	5	160	214	23	3.4	bdl
10	Balughata Primary School	Haldia	Tertiary	8.18	1739	bdl	311	378.2	324	64	40	64	10	200	276	51	5.7	1.13
11	Kamarda	Khejuri I	Tertiary	8.28	1281	bdl	201	353.8	196	18	9.5	58	1	150	186	27	2.8	0.95
12	Padurveri	Khejuri II	Dune	7.89	2709	bdl	325	397	483	5.3	13	58	30	270	38	23	2.8	bdl
13	Khejuri ZeroPoint	Khejuri II	Dune	7.84	469.8	300.7	0	195.2	160	120.5	BDL	0.32	32	24.3	180	41.3	5.8	0.86
14	Khejuri Village	Khejuri II	Dune	7.50	1641	1050.2	0	225.7	185	347.4	BDL	0.49	52	38.8	290	184.3	53.8	0.79
15	Sherkhanchak	Khejuri II	Tertiary	7.85	1265	bdl	104	353.8	224	2.2	2.5	52	11	175	191	31	3.6	bdl
16	Ramchak	Khejuri II	Tertiary	8.5	1269	bdl	140	329.4	238	8.1	7.6	48	12	170	133	27	4.7	1.64
17	Kastala(Dasp)	Khejuri II	Tertiary	7.8	1350	bdl	425	519	149	19	2.3	130	12	375	155	12	5.2	bdl
18	Kastala Ramkrishn Ashram	Khejuri II	Tertiary	7.96	1370	bdl	365	445	100	72	42	98	7	275	48	23	1.8	1.05
19	Khejuri	Khejuri II	Tertiary	8.04	1044	bdl	410	500	107	44	4	58	6	170	5	20	1.6	Bdl

20	Sundarpur(SouthBaga)	Khejuri II	Tertiary	8.01	1017	bdl	655	799	121	22	41	72	28	295	80	16	3.5	1.62
21	Kasaria EW	Khejuri II	Tertiary	7.65	944	604.2	0	420.9	345	109.9	BDL	0.5	34	35.2	230	115.1	5.6	
22	Diglabag	Kolaghat	Dug well	7.73	638	bdl	150	183	192	3.6	1.5	78	9	230	46	12	3.8	bdl
23	Siddha	Kolaghat	Quaternary	7.81	1321	bdl	760	927	188	34	2.3	78	17	265	138	66.3	1.5	8.4
24	Kolaghat	Kolaghat	Tertiary	8.1	816	bdl	403	330	53	2	1	42	1	120	133	15.6	2.5	0.64
25	Bathanberia	Kolaghat	Tertiary	7.85	916	bdl	372	305	78	29	15	44	15	55	184	3.9	3.8	0.4
26	Mecheda	Kolaghat	Tertiary	7.56	880	bdl	305	372	71	2.3	1.2	48	16	185	133	12	1.7	1.01
27	Gurchakli(SitalaMandir	Kolaghat	Tertiary	7.93	1843	bdl	40	49	46	58	42	26	12	115	345	43	0	bdl
28	Khandinan(No 8)	Kolaghat	Tertiary	7.88	1430	bdl	355	433	206	410	42	130	34	**205**	230	39	3.4	bdl
29	Mahisadal	Mahisadal	Dug well	8.11	1653	bdl	171	640.5	171	27	35	90	4	240	237	55	2.6	bdl
30	Bethkundu	Mahisadal	Tertiary	7.74	1090	bdl	55	427	128	9	2.3	66	5	185	159	8	7	bdl
31	Rangibasan Tw2	Mahisadal	Tertiary	7.19	1868	bdl	73	622.2	299	0	1	94	5	255	260	101	3.2	bdl
32	Kapasaria	Mahisadal	Tertiary	8.15	1363	bdl	73	335.5	220	65	26	62	4	170	209	43	5.4	bdl
33	Champi	Mahisadal	Tertiary	8.32	1149	bdl	183	323.3	167	33	11	50	6	150	173	35	1.9	bdl
34	Jalsai	Mahisadal	Tertiary	8	1124	bdl	260	317	142	28	19	68	2	180	163	20	5	0.39
35	Dakhin Moyna	Moyna	Tertiary	8.05	909	bdl	329	270	107	22	12	10	2	150	133	11.7	1.9	0.43
36	Paramananda Pur Vivekananda Bidya Pith	Moyna	Tertiary	7.84	710	bdl	354	290	32	25	21	20	6	125	108	11.7	2.6	bdl
37	ParamanandaPur Wss	Moyna	Tertiary	7.96	483	bdl	183	150	25	25	13	32	15	120	48	7.8	2	0.31
38	Bargodagodar	Nandakumar	Tertiary	7.72	1476	bdl	372	305	256	2	18	36	21	225	200	15.6	3.4	0.34
39	Khejurberia	Nandakumar	Tertiary	7.95	2655	bdl	519	425	622	0	14	12	2	490	350	50.7	3.8	4.52

40	Sitalpur Jalpai	Nandakumar	Tertiary	8.06	2183	bdl	470	385	462	0	0	44	9	440	260	42.9	4.5	bdl
41	Thenkuachak	Nandakumar	Tertiary	8.16	1253	bdl	315	384	178	35	43	58	9	180	202	23	5.8	1.24
42	Sonachuraph 2	Nandigram 1	Tertiary	7.86	966	bdl	256	420.9	78	20	1.1	48	7	150	156	16	3.6	bdl
43	Gholpukur	Nandigram 2	Tertiary	7.95	934	bdl	146	317.2	107	32	21	52	9	165	131	12	1.9	0.53
44	Maheshpur	Nandigram I	Tertiary	7.53	1110	710.4	0	292.8	240	198.5	3.4	0.88	40	48.5	300	120.5	9.8	
45	Gobindanagar	Panskura	Tertiary	7.94	536	bdl	232	190	36	5	1	40	1	105	60	7.8	3.1	0.51
46	Dokanda	Panskura	Tertiary	8.08	1874	bdl	616	505	277	4.6	12	18	2	190	281	81.9	1.8	0
47	Ratulia Dolbar	Panskura	Tertiary	8.06	522	bdl	232	190	25	21	16	28	16	250	3	1.95	0	6.72
48	Gotpota	Panskura	Tertiary	8.14	495	bdl	244	200	18	5	7	14	4	165	28	23.4	1.8	1.85
49	Gopimohanpur	Panskura	Tertiary	7.23	817	bdl	384	315	46	13	5.2	26	7	120	110	31.2	2.5	1.13
50	Deulbrah	Panskura	Tertiary	7.79	900	bdl	311	255	121	15	7.1	16	2	155	131	7.8	3.8	7.22
51	Gumai	Panskura	Tertiary	7.61	828	bdl	190	232	25	20	7.5	40	4	115	138	11.7	5.9	bdl
52	Amdan	Panskura	Tertiary	7.94	530	bdl	355	433	18	23	8.1	38	4	110	69	3.9	4.7	bdl
53	Pitpur	Panskura	Tertiary	8.09	452	bdl	210	256	25	27	15	12	15	90	50.6	19.5	5.8	0.54
54	Mahisda	Sahid Matangini	Tertiary	7.93	744	bdl	354	290	14	15	7	8	1	140	97	7.8	4.6	bdl
55	Dariala	Sahid Matangini	Tertiary	8.01	777	bdl	325	397	57	43	31	66	2	175	92	8	2.3	10.53
56	Chatra	Sahid Matangini	Tertiary	7.62	614	bdl	235	287	60	15	12	68	2.4	180	52.9	7.8	6.7	0.52
57	Dhenkua	Sutahata	Tertiary	7.96	1093	bdl	183	390.4	139	21	5	56	2	150	166	23	4.7	bdl
58	Asadtalia	Sutahata	Tertiary	8.1	1352	bdl	85	402.6	231	25	8.2	8	4	35	278	35	1.6	0.94
	ChaitanyapurZone II																	

59	Bhupatinagar	Sutahata	Tertiary	8.2	1481	bdl	128	433.1	267	8	12	46	12	165	258	55	1.7	1.95
60	Basudevpur HighSchool	Sutahata	Tertiary	7.83	1445	bdl	128	274.5	284	75	20	54	6	160	248	39	3.5	6.91
61	Hokhali	Sutahata	Tertiary	7.72	972	bdl	73	298.9	121	52	14	32	7	110	161	20	4.1	0.32
62	Chapbasan	Tamluk	Tertiary	8.01	1685	bdl	476	390	302	8	10	20	7	215	276	19.5	0.31	1.51
63	Simulia	Tamluk	Tertiary	7.92	834	bdl	378	310	71	4	2	52	17	110	138	7.8	1.2	1
64	Anantapur Zoneii	Tamluk	Tertiary	8	2416	bdl	580	475	498	30	5	14	2	315	403	15.6	1.6	1.12
65	Kakurkhana	Tamluk	Tertiary	7.89	891	bdl	415	340	43	9	11	18	5	100	140	31.2	1.5	0
	Minimum			**7.19**	**452.00**	**300.67**	**0.00**	**48.80**	**14.22**	**0.00**	**0.00**	**0.32**	**1.22**	**24.27**	**3.45**	**1.95**	**0.00**	**0.00**
	Maximum			**8.50**	**3742.00**	**1050.24**	**760.00**	**1091.90**	**657.68**	**410.00**	**43.00**	**266.00**	**52.00**	**700.00**	**489.90**	**184.30**	**53.80**	**10.53**
	Mean			**7.92**	**1235.06**	**666.37**	**266.44**	**373.37**	**179.15**	**39.81**	**14.15**	**48.25**	**10.45**	**185.03**	**174.00**	**32.93**	**4.08**	**2.13**
	Median			**7.94**	**1111.00**	**657.28**	**256.20**	**353.80**	**149.31**	**22.00**	**11.00**	**48.00**	**7.29**	**170.00**	**161.00**	**23.40**	**3.20**	**1.01**
	Standard Deviation			**0.24**	**592.91**	**309.25**	**166.83**	**164.52**	**140.98**	**69.13**	**12.40**	**39.49**	**10.45**	**108.02**	**95.48**	**32.93**	**6.61**	**2.78**

8.0 AQUIFER MANAGEMENT PLAN

8.1 Major Ground Water Related Issues in the Area

- Except 3 blocks, Kolaghat, Panskura and Moyna; other blocks comprise parts of coastal blocks in West Bengal
- Both the two major Aquifer Systems, Aquifer I and Aquifer II, under semi-confined to confined condition, phreatic zones insignificant, present in some patches, not developed/or accepted socially
- The occurrence of brackish water at shallower depth in Quaternary Aquifers (Aquifer I), in costal blocks restrict ground water development for irrigation uses in these blocks.
- The water supply tube wells of PHED, Govt of West Bengal are confined to Tertiary aquifers only, and the tube wells are usually very deep. Therefore, in most of the cases the cost of installation is higher.
- Problem of morning Salinity has been reported in number of tube wells in costal blocks of the study area. Owing to the higher brackish to saline nature of the overlying Aquifer I leakage in the drinking water tube wells has raised the EC even more than 20000 µS/cm.
- Long-term water level trend of water level in Aquifer I (Quaternary) and in Aquifer II (Tertiary) shows significant decline @ 20-60 cm /yr both in pre and post monsoon time
- The recharge area for Quaternary and Tertiary are far, towards North West Marginal sedimentary area. The direct rainfall recharge is insignificant.
- Dune sands present along coastal tracts of Khejuri II blocks, are not explored for sustainable ground water uses.

To formulate the proper Aquifer Management Plan, it is required to understand the total available ground water resources, its quality and status of present development. On the basis of these study sustainable effective management measures may be advocated

8.2 Ground Water Management Plan for Drinking and Domestic Sectors:

In West Bengal, PHED, Govt of West Bengal is entrusted with the water supply to the population in rural area and in urban area with assistance from Municipality/Municipal corporations. An assessment of present commissioned and ongoing water supply schemes in Purba Medinipur district, has indicated the blocks or the parts of the blocks in the study area which are uncovered through water supply schemes. The water supply schemes cover single and multiple villages. Besides the commissioned ground water-based supply schemes number of ongoing schemes are also under process of installation. Tentative block wise estimates have been made on the total population covered through the present ground water based commissioned and ongoing schemes. It is assessed that about 47% of the total population is under coverage of water supply schemes. And rest 1513907 populations are to be covered. In order to cover the remaining population in the study area additional 22.1030 MCM of annual resource is required.

It is also to mention that, besides the ground water-based water supply schemes, few surface water supply schemes are also in operation or proposed to be made operational in study area. Geonkhali Water Supply Schemes involves raw water treatment from river Rupnarayan and supply water to the Haldia town. The scheme presently has been handed over to Haldia Development Authority. A water supply scheme is under commissioning at Kolaghat block which proposes to draw water from Rupnarayan River and supply water to entire Kolaghat block with 31 MLD capacity water treatment plant. Another surface water based scheme covering Nandakumar, Chandipur, Nandigram I and Nandigram II is also under proposal.

Table 8.1 Population coverage by existing Water Supply Schemes

Name of the block	Total population	Covered population	Population (as per Census 2011)to be covered by water supply schemes	Annual Resource required tocater the population @40lpcd inmcm
Kolaghat	290124	75103	215021	3.1393

Panskura	283303	73547	267688	3.9082
Panskura Municipality	57932			
Moyna	226927	61164	165763	2.4201
Sahid Matangini	199210	89899	109311	1.5959
Tamluk	217776	167381	115701	1.6892
Tamluk Municipality	65306			
Nandakumar	262998	171374	91624	1.3377
Mahisadal	206277	162149	44128	0.6443
Chandipur	188219	99725	88494	1.2920
Nandigram I	207835	63177	144658	2.1120
Nandigram II	123219	75899	47320	0.6909
Khejuri II	139463	103682	35781	0.5224
Haldia	97992	136511	162308	2.3697
Haldia Municipality	200827			
Sutahata	123724	97614	26110	0.3812
Total	2891132	1377225	1513907	22.1030

However, based on the above estimate of coverage from existing and ongoing WSS from ground water, the provision to supply water from ground water in the study area will be reviewed.

The annual resources which will be required to cater the uncovered population in the study area has been estimated. Based on the study, it is proposed that, in inland blocks (Kolaghat, Panskura, Moyna and in parts of Sahid Matangini) and where existence of fresh Quaternary aquifer has been reported (Khejuri II), the remaining supply from ground water may be accomplished utilising both the aquifer. On the other hand, in the coastal blocks, where, the Tertiary or the aquifer II has so far been proved as the only source of fresh water, may be utilised for supply of drinking water. Considering the average discharge of Quaternary and Tertiary aquifer (from map data) in respective blocks and average 8 hours running per day, annual unit draft of one tube well has been assessed. Therefore, the total number of **32 tube wells** are proposed in Quaternary aquifer and **68 tube wells** in Tertiary aquifer to meet the demand from ground water resource in the study area. The recommended number of tube wells will cater the remaining need of 22.1030 MCM. The cumulative instorage resource in Aquifer I (Kolaghat, Panskura, Moyna, Sahid Matangini and Khejuri II) and Aquifer II in study area is 151.47 MCM.

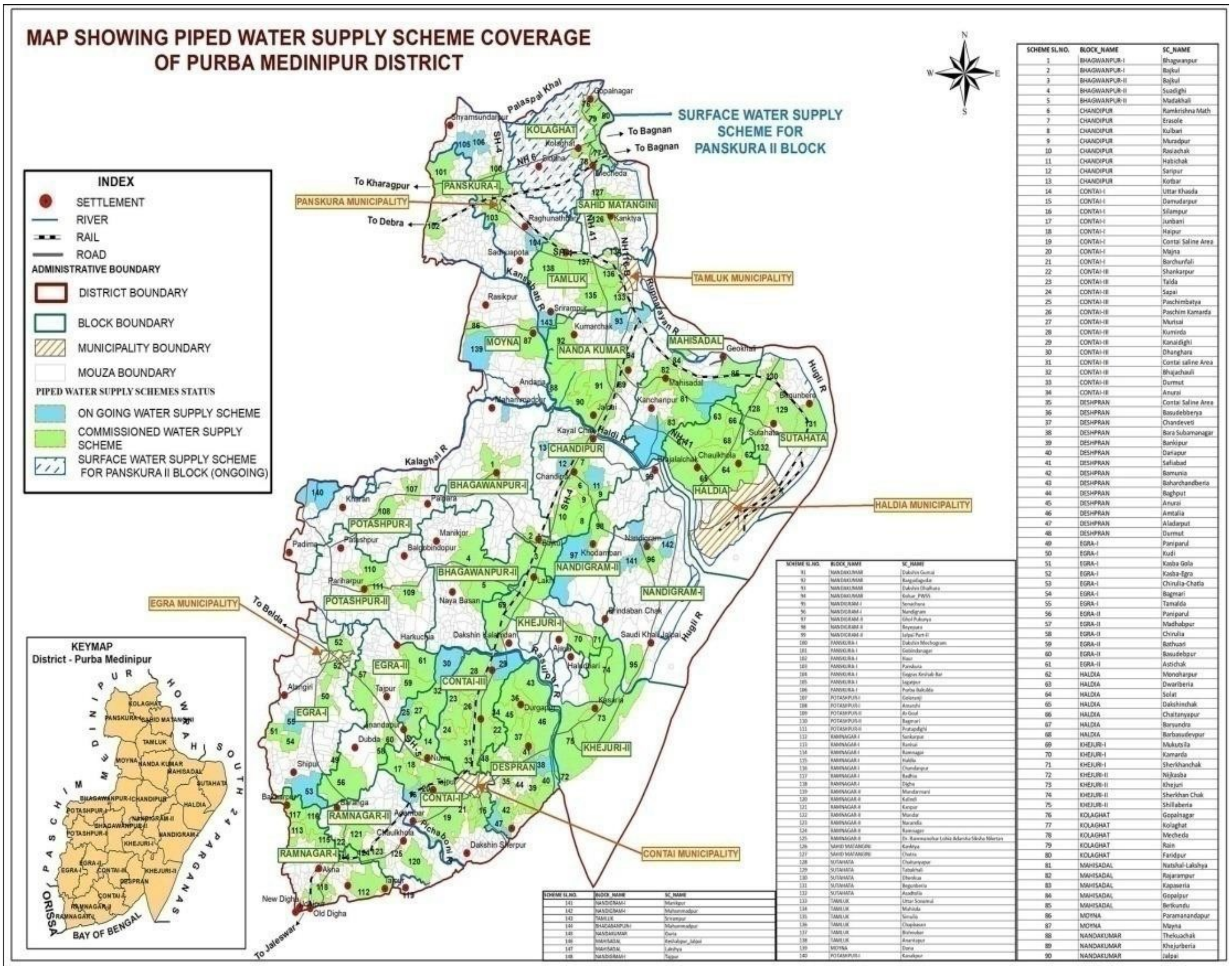


Table 8.2 Coverage under Piped Water Supply Schemes in Purba Medinipur District

Table 8.3 Development proposal for (Aquifer I) Quaternary and Aquifer II (Tertiary) Aquifer

Name of theblock	Geographi calarea (in Sq.Km.)	Annual Resource required tocater the uncovered population @40lpcd inMCM	Annual resource proposed to be utilised from QuaternaryAquifer in MCM	Annual resource proposedto be utilised from Tertiary Aquifer inMCM	Total annualunit draft of one TW in MCM (considering average discharge ofTertiary and8 hrs/day running)	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary and 8 hrs/day running)	No of tube well required in Quaternaryaquifer	No of tube well required in Tertiary aquifer
Kolaghat	145.8	3.14	1.26	1.88	0.13	0.29	9	6
Panskura	227.1	3.91	1.56	2.34	0.13	0.26	11	8
Moyna	158.7	2.42	0.97	1.45	0.13	0.26	7	5
Sahid Matangini	97.8	1.60	0.64	0.96	0.13	0.35	4	2
Tamluk	113.1	1.69	0.00	1.69		0.35	0	4
Nandakumar	165.7	1.34	0.00	1.34		0.26	0	5
Mahisadal	146.5	0.64	0.00	0.64		0.26	0	2
Chandipur	137.6	1.29	0.00	1.29		0.18	0	7
Nandigram I	181.8	2.11	0.00	2.11		0.20	0	10
Nandigram II	105.7	0.69	0.00	0.69		0.18	0	3
Khejuri II	137.5	0.52	0.21	0.31	0.15	0.29	1	1
Haldia	65.4	2.37	0.00	2.37		0.18	0	13
Sutahata	79.54	0.38	0.00	0.38		0.18		2
Total		22.10	Total				32	68

Both the aquifers in the area are under semi confined to confined condition. Therefore, further development of these aquifers will definitely affect the ground water regime in the area. The tentative decline of piezometric surface for each block for individual aquifer system has been assessed. It is observed that the probable decline of piezometric surface in Aquifer I is 2.24-24.19 m and the probable decline piezometric surface in Aquifer II is 3.35-36.29 m. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation in these aquifers should always be compensated by construction of suitably design artificial recharge structures in respective aquifers. Further, the total ground water flow through the Tertiary aquifer in the study area has been assessed as 48.73 MCM. The annual resource proposed to be utilised from Tertiary aquifer is 17.47 MCM to meet the demand need for uncovered population.

Table 8.4 Probable Effects of Development on Ground Water Regime

Name of the block	Geographical area (in Sq.Km.)	Annual resource proposed to be utilised from Quaternary Aquifer in MCM	Annual resource proposed to be utilised from Tertiary Aquifer in MCM	Decline of piezometric surface in Quaternary Aquifer (in m)	Decline of piezometric surface in Tertiary aquifer(in m)
Kolaghat	145.79	1.2557	1.8836	24.19	36.29
Panskura	227.14	1.5633	2.3449	17.77	26.66
Moyna	158.69	0.9681	1.4521	17.14	25.7
Sahid Matangini	97.82	0.6384	0.9576	18.33	27.5
Tamluk	113.07	0.0000	1.6892		36.24
Nandakumar	165.7	0.0000	1.3377		11.87
Mahisadal	146.48	0.0000	0.6443		6.47
Chandipur	137.58	0.0000	1.2920		13.81
Nandigram I	181.84	0.0000	2.1120		17.08
Nandigram II	105.74	0.0000	0.6909		9.61
Khejuri II	137.46	0.2090	0.3134	2.24	3.35
Haldia	65.44	0.0000	2.3697		19.9
Sutahata	79.54	0.0000	0.3812		7.05

Ground Water Management Plan for Irrigation Sectors:

Agriculture is one of the principal sources of livelihoods of the people in the area. The major crop in the area includes paddy followed by pulses, potato, mustard and little wheat and jute. The aman, the principal paddy, is rainfed. The boro paddy which is solely dependent on irrigation water also grown in considerable amount. The production of other major crops like wheat, potato, pulses, oilseed etc. is comparatively less in the study area for soil type or other agrarian issues and for scarcity of fresh irrigation water supply. Irrigation through ground water schemes are limited in coastal area due to brackish nature of ground water and occurrence of fresh water in deeper Tertiary aquifers. The Quaternary aquifers or the Tertiary aquifers wherever utilized in the study area for irrigation uses bear heavy lowering of piezometric surface. Therefore, further installation of ground water structures for irrigation uses in either aquifer in the study area is not recommended at present. Therefore, crop diversification and modification of cropping pattern; (keeping the fundamental crops unchanged) may increase the cropping intensity in a particular block on the other hand reduce exploitation of irrigation water by merely reducing irrigation of 10% of water intense boro crops. The tentative water column required for different crops is given in Table 8.5.

Table 8.5 Crop Water Requirements

Crop	Water Requirement(mm)	Crop	Water Requirement(mm)
Rice	900-2500	Chilies	500
Wheat	450-650	Sunflower	350-500
Sorghum	450-650	Castor	500
Maize	500-800	Bean	300-500
Sugarcane	1500-2500	Cabbage	380-500
Groundnut	500-700	Pea	350-500
Cotton	700-1300	Banana	1200-2200
Soybean	450-700	Citrus	900-1200
Tobacco	400-600	Pineapple	700-1000
Tomato	600-800	Gingerly	350-400
Potato	500-700	Ragi	400-450
Onion	350-550	Grape	500-1200

Total area of production of paddy in the study area is 140679 ha, among which 61966 ha is under boro paddy cultivation. By proposing 10% reduction in bore cultivation, the area under boro cultivation in study area becomes 55768 ha which results in saving of 7438 ham of water. This water is utilized proportionally for providing irrigation to less water crops like wheat, oilseeds (mustard, sunflower), pulses, potato in few places, other horticulture and floriculture crops etc. The selection of crops where additional water would be applied are judged on the basis of prevailing irrigation practices in the area. The area being underlain by poorly drained soil, therefore, wheat, and potato cultivation is restricted in the area. In Kolaghat and Panskura block floriculture crops like Belle, tuberose, marigold are grown, therefore surplus water in these blocks may be utilized for floriculture crops. Thus, the saved water can be utilized to create irrigation potential of 19519 ha and the effective increase in irrigation potential is 13322 ha (Table 8.6). Total cultivable area in the study area is 130536 ha and 66850 ha has been brought under culturable command area under surface and ground water schemes. Therefore, the remaining area to be braught under CCA is 65356 ha. Therefore, by proposed intervention by change in cropping pattern by reducing only 10% of boro area 20% of the remaining area can be brought under irrigation command in the study area.

In Khejuri II block, the well-drained dune soil is suitable for cultivation of pan baroj due to its poor susceptibility to stagnant water. Cashew crops, betel leaves may be cultivated from freshwaterresource in dune sands to create additional irrigation potential in Khejuri II block.

Table 8.6 Proposed Intervention in Irrigation Practice in the Study Area to Increase Effective Irrigation Coverage with Maintaining the Present Ground Water Draft

Present area under Boro, and reduction of 10% of Boro area						Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation						Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Sl no	Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction(ha)	Volume of Irrigation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor:30 cm)	Potato (Delta factor:60 cm)	Cashew/Betel Leaves	Floriculture (Bell, Marigold, tuberose) (Delta factor:22.5 cm)	Total additional area in ha	Effective Increase in area(ha)
1	Tamluk	4885	1.2	4397	585.60	520.53	488.00	542.22				1550.76	1062.26
2	Sahid Matangini	4826	1.2	4343	579.60	515.20	483.00	536.67				1534.87	1052.27
3	Panskura-I	11926	1.2	10733	1431.60		1191.81	1589.08			2118.77	4899.65	3707.05
4	Kolaghat	8249	1.2	7424	990.00		824.18	1098.90			1465.20	3388.28	2563.38
5	Moyna	8997	1.2	8097	1080.00		899.10		599.40			1498.50	598.80
6	Nandakumar	9327	1.2	8394	1119.60		932.07	1242.76	621.38			2796.20	1863.50
7	Chandipur	2462	1.2	2216	295.20		245.75	327.67	163.84			737.26	491.06
8	Mahishadal	6356	1.2	5720	763.20		635.36	847.15	423.58			1906.09	1270.49
9	Nandigram-I	810	1.2	729	97.20		80.92	107.89	53.95			242.76	161.76
10	Nandigram-II	1470	1.2	1323	176.40		146.85	195.80	97.90			440.56	293.56
11	Sutahata	1206	1.2	1085	145.20			161.17				161.17	40.57
12	Haldia	432	1.2	389	51.60			57.28				57.28	14.08
13	Khejuri-II	1020	1.2	918	122.40		101.90	135.86	67.93	From Dune Sands		305.69	203.69

Total	61966		55768	7437.60	1035.73	6028.94	6842.45	2027.97		3583.97	19519.06	13322.46	

8.3 Management Interventions through Rainwater Harvesting and Artificial Recharge

The area receives plenty of rainfall, but the undistributed rainfall causes huge amount of water to drain to the sea. On the other hand, the area being predominantly underlain by clay, direct rainfall infiltration is very less, resulting high volume of runoff. The non-committed runoff, thus produced, may be diverted for water harvesting either for conservation or for artificial recharge to the depleted aquifer in the area. The volume of monsoon runoff that can be harnessed without creating any adverse impact on environment is estimated by applying Druvanarayana, 1993(Table 8.7). Thus, the non-committed surface runoff after deducting e flow component is **293.11 MCM.**

Table 8.7 Estimation of Non-Committed Runoff for Rain Water Harvesting

Name of the block	Geographical area (in Sq.Km.)	Normal monsoonrainfall in m (50 yrs data)	Volume of Monsoon rain fall in MCM=(Rn X A)	Run off co-efficient from Dhruvanaray ana,1993(Land slope, type of land and soil type) 'C' land slope 0-5%	Major type of soil availablein that block	Total volume of surface runoff available Annually 'Vt' (RnXAXC) MCM	75% of 'Vt' = V MCM	50% of V (Non committed) =Vnc MCM	60% of Vnc(considering e-flow)= Vf MCM
Kolaghat	145.79	1.3643	198.90	0.50	Clay/silty Loam	99.45	74.59	37.29	22.38
Panskura	227.14	1.3643	309.89	0.50	Clay/silty Loam	154.94	116.21	58.10	34.86
Panskura Municipality	19.94	1.3643	27.20	0.50	Clay/silty Loam	13.60	10.20	5.10	3.06
Moyna	158.69	1.3643	216.50	0.50	Clay/silty Loam	108.25	81.19	40.59	24.36
Sahid Matangini	97.82	1.3643	133.46	0.50	Clay/silty Loam	66.73	50.05	25.02	15.01
Tamluk	113.07	1.3643	154.26	0.50	Clay/silty Loam	77.13	57.85	28.92	17.35
Tamluk Municipality	17.86	1.3643	24.37	0.50	Clay/silty Loam	12.18	9.14	4.57	2.74
Nandakumar	165.7	1.3643	226.06	0.50	Clay/silty Loam	113.03	84.77	42.39	25.43

Mahisadal	146.48	1.3643	199.84	0.50	Clay/silty Loam	99.92	74.94	37.47	22.48
Chandipur	137.58	1.3643	187.70	0.50	Clay/silty Loam	93.85	70.39	35.19	21.12
Nandigram I	181.84	1.3643	248.08	0.50	Clay/salty Loam	124.04	93.03	46.52	27.91
Nandigram II	105.74	1.3643	144.26	0.50	Clay/silty Loam	72.13	54.10	27.05	16.23
Khejuri II	137.46	1.3643	187.54	0.50	Clay/silty Loam	93.77	70.33	35.16	21.10
Haldia	65.44	1.3643	89.28	0.50	Clay/silty Loam	44.64	33.48	16.74	10.04
Haldia Municipality	109.65	1.3643	149.60	0.50	Clay/silty Loam	74.80	56.10	28.05	16.83
Sutahata	79.54	1.3643	108.52	0.50	Clay/silty Loam	54.26	40.69	20.35	12.21

This volume of water may be utilized for rainwater harvesting by Artificial Recharge or byconservation structures.

8.4 Rainwater Harvesting for Artificial Recharge

The two aquifer systems, Aquifer I and Aquifer II witness's deeper water level and post monsoon piezometric surface lies at 7.5 m to 13.00 mbgl. The water level throughout the area is deeper and experiences significant long-term falling trend of water level. Therefore, the deeper aquifer in the entire area is suitable for artificial recharge. However, to account for the infeasible area 80% of the total area is considered as the area suitable for recharge. The available storage column/space (post-monsoon) for individual aquifer has been calculated for respective blocks. Total volume of available storage space is calculated by multiplying storage area by storativity. Considering the efficiency of the structure as 75%, the total water required to fill the storage space has been assessed. It is observed that 10.1726 MCM of water is required to fill the available storage space in Tertiary aquifer in the study area. Considering paucity of structures in Aquifer I (Quaternary), storage space available for Quaternary has been calculated for five blocks only, Kolaghat, Panskura, Moyna, Sahid Matangini and Khejuri II block. The volume of water required to fill the available storage space in Quaternary aquifer is 2.6282 MCM (Table 8.8).

The aquifer being under confined condition, limited recharge feasibility exist. This volume of water, 10.1726 MCM and 2.6282 MCM is proposed to be artificially recharged to Tertiary and Quaternary aquifer respectively by constructing injection well in respective aquifers. Each injection well to be provided with roof top harvesting mechanism to hold the rain water which is diverted back to the aquifer. Considering unit roof area of 100 sq m, total

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8)in MCM	No of RTRWH with injection well required for Tertiary (4/9)	No of RTRWH with injection well required for Quaternary (5/9)

annual rainfall and 80% runoff coefficient the unit capacity of one roof top structures is 0.0133072 MCM.

Table 8.8 Water Required to fill the Storage Space and feasible number of structures

Therefore, to divert back 10.1726 MCM of water in Tertiary Aquifer 764 injection wells with Roof top Rain Water Harvesting (RTRWH) system may be required. Similarly, to put back 2.6282 MCM of water in Quaternary aquifer design of 197 RTRWH structures with injection wells are recommended. Block wise requirement of structure for individual aquifer system is furnished in Table 8.8.

1	2	3	4	5	9	10	11
Kolaghat	145.79	22.3764	0.4517	0.2281	0.0133072	34	17
Panskura	227.14	34.8623	0.8604	0.8148	0.0133072	65	61
Panskura Municipality	19.94	3.0605	0.0755	0.0715	0.0133072	6	5
Moyna	158.69	24.3563	0.5981	0.5837	0.0133072	45	44
Sahid Matangini	97.82	15.0138	0.3250	0.3335	0.0133072	24	25
Tamluk	113.07	17.3544	0.3696		0.0133072	28	
Tamluk Municipality	17.86	2.7412	0.0584		0.0133072	4	
Nandakumar	165.7	25.4323	1.1102		0.0133072	83	
Mahisadal	146.48	22.4823	1.0248		0.0133072	77	
Chandipur	137.58	21.1163	0.9208		0.0133072	69	
Nandigram I	181.84	27.9095	1.0946		0.0133072	82	
Nandigram II	105.74	16.2294	0.7276		0.0133072	55	
Khejuri II	137.46	21.0979	0.7807	0.5967	0.0133072	59	45
Haldia	65.44	10.0440	0.4678		0.0133072	35	
Haldia Municipality	109.65	16.8295	0.7838		0.0133072	59	
Sutahata	79.54	12.2081	0.5237		0.0133072	39	
Total						764	197

8.5 Probable Impact of Proposed Artificial Recharge Structures:

There are three municipality and 15 census town in the study area. For implementation of rainwater harvesting scheme for artificial recharge to ground water, Panskura, Tamluk and Haldia Municipality area and the census towns in the study area may be selected at first phase. The scheme may then be extended to the rural area. The probable impact on the ground water regime of the respective aquifers has also been assessed. It is observed that in successful implementation of recharge structures in Tertiary aquifer the water level is likely to rise 8.35 m to 10.50 m whereas in case of Quaternary Aquifer the water level rise will be 4.5 to 10.50 m.

Table 8.9 Estimated Impact on Ground Water Regime

Name of the block	Geographical area (in Sq.Km.)	No of RTRWH with injection well required for Tertiary	Impact on water level (rise in m)	No of RTRWH with injection well required for Quaternary	Impact on water level (rise in m)
Kolaghat	145.79	34	8.70	17	4.39
Panskura	227.14	65	10.64	61	10.08
Panskura Municipality	19.94	6	10.64	5	10.08
Moyna	158.69	45	10.59	44	10.33
Sahid Matangini	97.82	24	9.33	25	9.58
Tamluk	113.07	28	9.18		
Tamluk Municipality	17.86	4	9.18		
Nandakumar	165.7	83	9.85		
Mahisadal	146.48	77	10.29		
Chandipur	137.58	69	9.84		
Nandigram I	181.84	82	8.85		
Nandigram II	105.74	55	10.12		
Khejuri II	137.46	59	8.35	45	6.38
Haldia	65.44	35	10.51		
Haldia Municipality	109.65	59	10.51		
Sutahata	79.54	39	9.68		
Total		764		197	

8.6 Rain Water Harvesting for Conservation/Irrigation Tanks

Very limited amount of available non committed runoff can be diverted underground to augment the depleted ground water reserve due to limited storage space in confined Tertiary/Quaternary aquifers. Therefore, major part of the remaining non committed runoff may be harnessed through conservation structures. Since, no further increase in tube wells for irrigation purposes is desirable, therefore, to increase the irrigation potential from harvested rainwater storage /conservation/ irrigation tanks may be constructed in the rural area. If unit capacity of one tank be 0.05 mcm, the remaining non committed runoff may be utilized by construction of about 5173 tanks in suitable locations in the study area. The block wise feasible number is given in Table 8.10. To initiate the project of construction of storage tanks each habitation in the study area may be targeted to provide with one or two tanks in the first phase.

Table 8.10 Design of Storage Tanks for Conservation for Irrigation Uses

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Vol of water kept for conservation/storage tanks in MCM	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks
Kolaghat	145.79	22.3764	21.6966	0.05	434
Panskura	227.14	34.8623	33.1872	0.05	664
Moyna	158.69	24.3563	23.1746	0.05	463
Sahid Matangini	97.82	15.0138	14.3554	0.05	287
Tamluk	113.07	17.3544	16.9848	0.05	340
Nandakumar	165.7	25.4323	24.3221	0.05	486
Mahisadal	146.48	22.4823	21.4575	0.05	429
Chandipur	137.58	21.1163	20.1955	0.05	404
Nandigram I	181.84	27.9095	26.8149	0.05	536
Nandigram II	105.74	16.2294	15.5018	0.05	310
Khejuri II	137.46	21.0979	19.7204	0.05	394
Haldia	65.44	10.0440	9.5762	0.05	192
Sutahata	79.54	12.2081	11.6844	0.05	234
Total					5173

8.7 Utilization of Conserved Water and Creation of Additional Irrigation Potential:

A considerable volume of the conserved water (here it is assumed 25%) is lost through evaporation. Considering occurrence of surface clay in the entire study area the percolation loses would be negligible. If the remaining water be utilized for direct irrigation for rabi crops/vegetable/ horticulture etc. considering average required delta factor as 50 cm, about 38800 ha additional irrigation potential can be generated (Table 8.11).

Table 8.11 Additional Irrigation Potential that Can be Created from tank irrigation

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Vol of water for conservation/storag etanks in MCM	Evaporation loss(25% of storage) MCM	Water can be utilised for irrigation ham	Additional area can be brought under irrigationconsidering average delta factor of 50 cm forRabi crops / vegetable / horticulture etc.(in ha)
Kolaghat	145.79	22.38	21.70	5.42	1627.25	3254.49
Panskura	227.14	34.86	33.19	8.30	2489.04	4978
Moyna	158.69	24.36	23.17	5.79	1738.09	3476.19
Sahid Matangini	97.82	15.01	14.36	3.59	1076.65	2153.30
Tamluk	113.07	17.35	16.98	4.25	1273.86	2547.72
Nandakumar	165.70	25.43	24.32	6.08	1824.16	3648.32
Mahisadal	146.48	22.48	21.46	5.36	1609.31	3218.62
Chandipur	137.58	21.12	20.20	5.05	1514.66	3029.33
Nandigram I	181.84	27.91	26.81	6.70	2011.11	4022.23
Nandigram II	105.74	16.23	15.50	3.88	1162.64	2325.27
Khejuri II	137.46	21.10	19.72	4.93	1479.03	2958.06
Haldia	65.44	10.04	9.58	2.39	718.21	1436.43
Sutahata	79.54	12.21	11.68	2.92	876.33	1752.66

8.8 Final Implication of Application of Management Intervention in Irrigation Sectors

It is observed that, among the cumulative cultivable area of 130536 ha in the study area, 66850 ha culturable command area is created so far by existing ground water and surface water-based irrigation. The remaining 65356 ha area require further irrigation. A cumulative 48602 ha irrigation potential can further be generated by management intervention by changing the cropping pattern (reduction of bore area by 10%) and harvesting runoff through storage tanks (Table28). It is observed that 35-80 % of the remaining cultivable area thus, can be brought under irrigation coverage. However, in few blocks like Kolaghat, Panskura and Mahisadal, the additional area which can be brought under irrigation by the above management interventions are more than the actual requirement. Therefore, in these blocks suitable correction may be made either in cropping pattern or by reducing the number of tanks. In Chandipur block, the cultivable area is already under irrigation coverage by existing ground water or surface water schemes.

Table 8.12 Total Additional Irrigation Potential that can be Created

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Vol of water for conservation/storage tanks in MCM	Evaporation loss (25% of storage) MCM	Water can be utilised for irrigation ham	Additional area can be brought under irrigation considering average delta factor of 50 cm for Rabi crops / vegetable / horticulture etc.(in ha)
Kolaghat	145.79	22.38	21.70	5.42	1627.25	3254.49
Panskura	227.14	34.86	33.19	8.30	2489.04	4978
Moyna	158.69	24.36	23.17	5.79	1738.09	3476.19
Sahid Matangini	97.82	15.01	14.36	3.59	1076.65	2153.30
Tamluk	113.07	17.35	16.98	4.25	1273.86	2547.72
Nandakumar	165.70	25.43	24.32	6.08	1824.16	3648.32
Mahisadal	146.48	22.48	21.46	5.36	1609.31	3218.62
Chandipur	137.58	21.12	20.20	5.05	1514.66	3029.33

Nandigram I	181.84	27.91	26.81	6.70	2011.11	4022.23
Nandigram II	105.74	16.23	15.50	3.88	1162.64	2325.27
Khejuri II	137.46	21.10	19.72	4.93	1479.03	2958.06
Haldia	65.44	10.04	9.58	2.39	718.21	1436.43
Sutahata	79.54	12.21	11.68	2.92	876.33	1752.66

8.9 Summary and Findings:

- The study area comprises alluvial coastal plains in the southern parts of the State. The coastal plains in Khejuri area are characterized by linearly disposed sand dunes covered with thick vegetation.
- In comparison to the other coastal districts in the State, North and South 24 Pargana district, the coastal distract of Purba Medinipur is characterized by three parallel to sub-parallel principal drainages, Rupnarayan, Haldi and Rasulpur from north to south. Deltaic sedimentation is not common.
- Panskura, Kolaghat, Moyna, parts of Sahid Matangini and Tamluk blocks may be considered as inland blocks and rest blocks are with coastal influences.
- The area is underlain by Quaternary and Tertiary sediments, the Quaternary deposits comprises Aquifer I and Tertiary deposits comprises Aquifer II. Besides Aquifer I and II, local less persistent dug well zone/phreatic and the dune sands comprises shallow phreatic aquifer.
- The entire area is under semi confined to confined condition with thick persistent clay cover.
- In general, the depth of the Tertiary increases towards southeast and the correlation of the stratigraphic units reveals undulating depositional surface.
- Considering brackish ground water in Quaternary aquifer in coastal blocks the operational ground water structures rare in Aquifer I, therefore, study is restricted to the inland blocks in Quaternary aquifer and the fresh Tertiary aquifers throughout the area.
- The piezometric surface in Quaternary (Aquifer I) and Tertiary (Aquifer II) are deep, -4

to -18 m wrt msl. The general ground water flow from NW-SE, however, due to local development the ground water flow has been modified by forming troughs and mounds.

- Both the aquifers' experiences steady long-term decline of piezometric surface. The average water level has been lowered from initial level of 6-10 m in 1991/2002 to around 24 m bgl. in 2017.
- Aquifer I and Aquifer II are very much extensive and potential. Huge thickness of Tertiary sands within 300 m depth, yields at 30-180 m3/hr for moderate drawdown. Transmissivity is also high.
- 48.73 MCM of annual ground water is flowing away through the Tertiary aquifer in the study area. This huge quantum of flow, along with influence of substantial development may result in steady lowering of ground water level.
- The available in storage resource in Aquifer I and Aquifer II is limited.
- The resource in dune sands, mostly fresh, may be harnessed separately for limited irrigation development or for local domestic uses after little treatment.
- The ground water in Aquifer I in coastal tract is brackish, whereas the Aquifer II is fresh. The ground water in the area is sodium chloride and sodium bicarbonate type.
- The heavy discharge of flow through the Tertiary aquifer, to some extent restrict saline water wedge, therefore, no adverse effect on salinity has been reported so far from the Tertiary aquifer despite of profound decline of piezometric surface.
- Ground water for drinking water supply so far be accomplished in the area from Tertiary aquifer (Aquifer II). To meet the demand of uncovered population from ground water, construction of 68 tube wells in Aquifer II and 32 tube well in five blocks in Aquifer I, has been recommended.
- To mitigate the further lowering of piezometric surface as a consequence of recommended development, construction of 764 injection wells with RTRWH and 197 injection wells with RTRWH has been recommended in Tertiary (aquifer II) and Quaternary (aquifer I) aquifer respectively.

- Construction of irrigation tube wells is not desirable at this instant. However, change in cropping pattern by reducing 10% of boro cultivation and subsequently increasing the production of mustard, pulses, horticulture and floriculture crops at favorable location will generate additional irrigation coverage with the existing water resource.
- The non-committed runoff may be harvested through construction of irrigation tanks in the rural sector of the study area. Thus, 5173 storage/ irrigation tanks have been recommended.
- The management intervention through change in cropping pattern and irrigation from storage tanks may create an additional irrigation potential of 48602 ha. Thus, on an average 75% of the remaining cultivable area in the study area may be brought under culturable command area.
- Further prospect of dune sands in Khejuri area may need to be studied in detail for sustainability of dune aquifer.
- Periodic monitoring of water level and quality is needed to detect any adverse effect on the ground water regime in dynamic coastal area.

BLOCK WISE AQUIFER MAPS AND MANAGEMENT PLAN OF PARTS OF PURBA MEDINIPUR, WEST BENGAL

9.0 MANAGEMENT PLAN OF CHANDIPUR BLOCK

9.1 Location, Demography and Rainfall

Chandipur block is a part of Tamluk subdivision earlier called as Nandigram III block. Chandipur is located at 22.0922°N latitude and 87.8562 °E longitude Bounded in the east by Mahisadal Block, in the north Moyna and Nandakumar block, in the south by Nandigram I block and in the west by Bhagawanpur I block of Purba Medinipur district.

- Subdivision: Tamluk
- Sub basin: Haldi
- Geographical Area: Chandipur: 137.58 sq km.
- Population (2011 Census)

Table 9.1 Total population of the Block

	Rural Population	Urban Population	Total
Block	176704	11415	188119

The block comprises 10 Gram Panchayets, 2 census towns, 109 villages, 185 habitations and 40077 households.

Table 9.2 Basic Demographic Detail of Chandipur Block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	HouseHolds	Population
1	Brajalalchak	7	23	4640	21250
2	Brindabanpur-i	7	10	3240	15440
3	Brindabanpur-ii	14	22	3857	19108
4	Chowkhali	15	22	4942	23167
5	Dibakarpur	8	13	3816	17380
6	Iswarpur	12	23	3415	16021
7	Jalpai	26	31	5334	24453
8	Kulbari	4	8	2157	10152
9	Nandapur Baraghuni	5	14	4234	20222
10	Usmanpur	11	19	4442	21238
	Total	**109**	**185**	**40077**	**188431**

Source: PHED, Govt of WB, Website

- **Normal Annual Rainfall** in the district: 1663.40 mm

Table 9.3 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall
Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

9.2 Physiographic and Drainage:

The block is a part of lower Gangetic plain and is a part of Haldi sub-Basin. The river Haldi is flowing in SE direction along the northern boundary of Chandipur community development block. The river witnesses tidal influences. The average elevation is 5 m amsl. The dominant soil type of the block is very poorly drained impermeable clayey soil. The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

9.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 9.4 Details of Land use pattern of block (area in ha)

Name of the block	Reporting area	Forest area	Area under non-agriculture wastes	Barren and un-culturable lands	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Net area sown
Chandipur	13586	0	3156			96				10334

9.4 Agriculture and Irrigation:

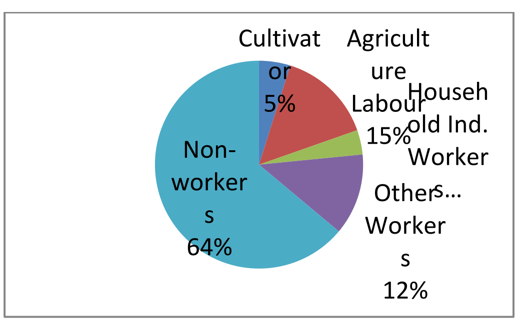


Figure 9.1 Distribution of persons engaged in agriculture and other workers/non workers in the Block

In Chandipur block, 64% of total population is non workers. It is evident from the above diagram that 20% of the total population in the block is engaged in agriculture either as cultivator or as agriculture labour, 4% comprises Household industrial workers and 12% comprises other worker.

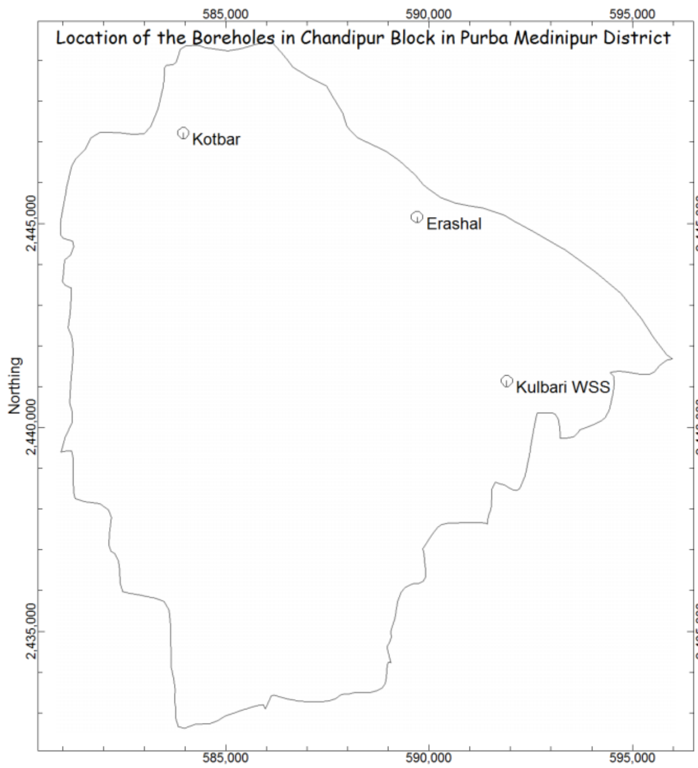
Cultivable area in the block is 10430 ha. Irrigation in the block is achieved by surface and ground water sources. The Culturable Command Area (CCA) created by surface water and ground water resources in the block is 12099 ha which already exceeds cultivable area in the block. 60% of the irrigation coverage achieved by surface water and the rest 40% by ground water sources. Therefore, both surface water and ground water has been utilized simultaneously in the block for generation of irrigation command area. Attempt may be initiated to bring further area under cultivation in the block. Surface irrigation network comprises canal irrigation, tanks, surface flow and lift irrigation. As per the District Statistical Handbook, 2014, 130 ha have been brought under irrigation through canal. A considerable area is brought under irrigation by numbers of tanks. Surface flow, lift irrigation comprises other mode of surface irrigation networks in the block. Ground water irrigation is limited and is accomplished mainly through shallow tube wells and limited numbers of deep tube wells. The CCA created by about 200 shallow tube wells is 4692 ha, besides that some more area is under irrigation through medium and deep tube wells.

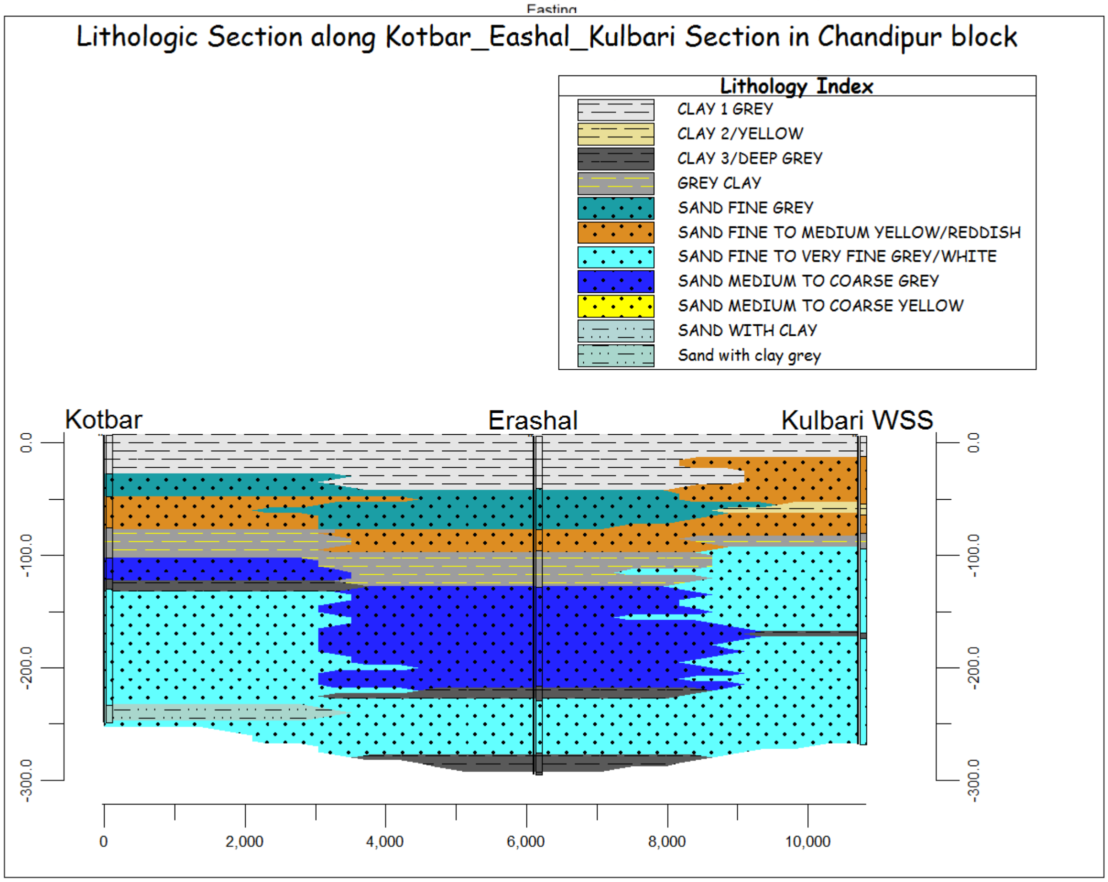
Table 9.5 CCA Created by Different Sources in the block (2013-14)

Block Name	Dugwell		Shallow Tubewell		Medium Tubewell		Deep Tubewell		Surface Flow		Surface Lift		CCA(ha.) Total CCA(ha.)		
	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	Ground Water	Surface Water	Total
Chandipur	1.00	2.20	194.00	4692.27	13.00	141.70	1.00	1.00	10.00	75.30	539.00	7187.20	4837.17	7262.50	12099.67

9.5 Geology and Sub-Surface Geology

The block is covered by Holocene sediments. The newer alluvium of Holocene age is underlain by Pleistocene Quaternary sediments. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt. Departments, the actual lithology and interpreted aquifer models are prepared, and aquifer systems has been classified.

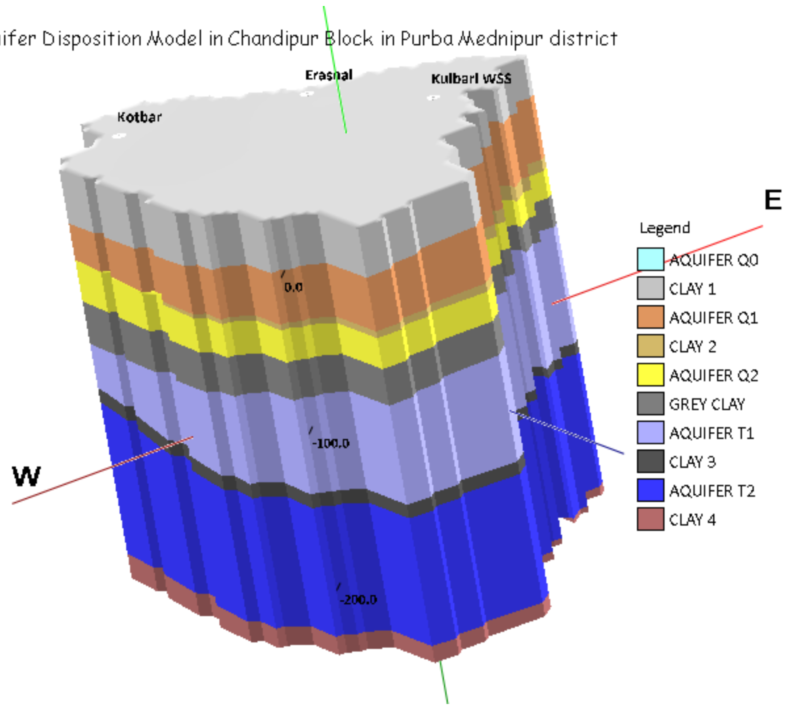




The lithology model reveals that the block is overlain by thick surface clay of 30 m thick. The surface clay is mostly gray in color representing younger alluvium. The lithology is represented by alternate sequence of sands of fine to medium and coarse and clay. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and tertiary boundary is marked by occurrences of thick gray clay. Tertiary gray clay is thick and consistent and is found to occur at an average depth of 89-115 mbgl. The average thickness of the Tertiary clay is 24 m.

9.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:

Aquifer Disposition Model in Chandipur Block in Purba Mednipur district



Aquifer Disposition along Kotbar_Erashal_Kulbari Section in Chandipur Block

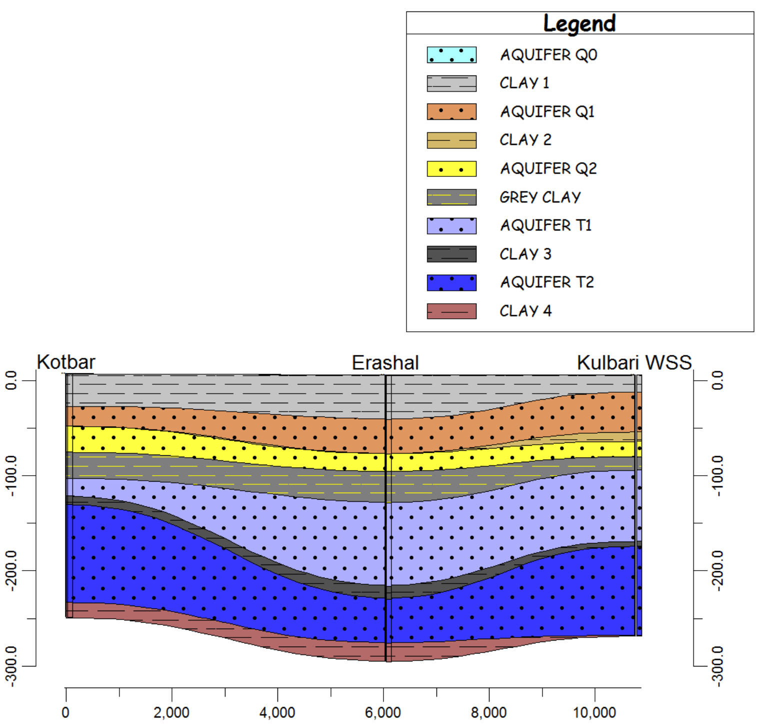


Table 9.6 Disposition of Aquifers and Q/T Boundary in Chandipur Block

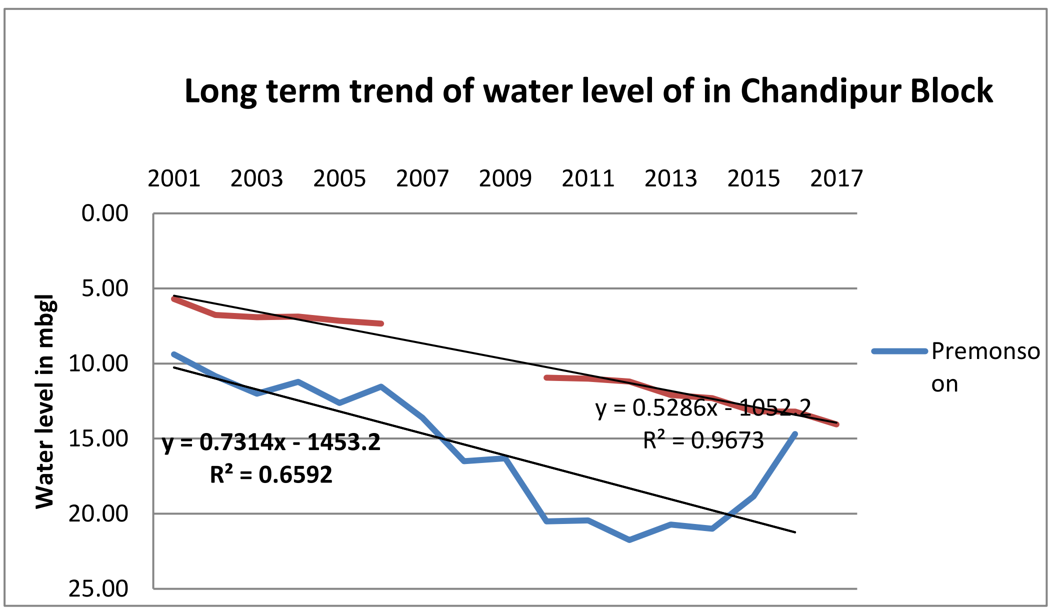
Block	Quaternary Aquifers						Q/T Boundary			Tertiary Aquifers					
	Q1			Q2						T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Chandipur	32.96	65.64	32.68	69.33	89.67	20.33	89.67	114.33	24.67	114.33	175.00	60.67	184.00	265.00	81.00

The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. Along a NW-SE section the individual aquifer system is disposed uniformly with local variation of thickness of individual layers. The separating clay between two quaternary aquifers; Q1 and Q2 are not manifested in Kotbar, Erashal area, thus forming single Quaternary aquifer system. The cumulative thickness of Tertiary aquifer in the area is more (140 m) than that of quaternary aquifers (50 m). Both the Tertiary aquifers are very thick and continuous in the block. A comparatively thin dark steel gray clay layer is found to separate the two tertiary aquifers.

Ground Water Regime

Groundwater, in both quaternary and tertiary aquifer system is under confined condition. Pre and post monsoon water level have been monitored from number of observation wells in Tertiary aquifer systems. Due to the paucity of the working tube wells in the quaternary aquifer, the monitoring data from the quaternary aquifer system was inadequate. The data of CGWB and SWID has been compiled and long-term water level 2002-2017 has been analyses from SWID data for Tertiary aquifer only. It is observed that Tertiary registers a long term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow from NW to SE and 10.4 m below sea level to 13.4 m below sea level in Tertiary aquifers. The ground water flow is influenced by local ground water development in the block.

Aquifer system	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m below msl)
Tertiary	5	18.4-19.4	13.05-14.20	70 cm fall	52 cm fall	-10.4 to-13.4 m



Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is about 50-140 m3/hr with moderate drawdown of 3-6 m. The specific capacity ranges between 23-28 m3/hr/m drawdowns. The shallow tube wells for irrigation uses lie within the dept range of 100-200 m.

Aquifer **Wise Ground Water Resource Availability**

The entire block is under confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl, therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area.

Table 9.7 Details of resource available in Tertiary aquifer (in MCM) in Block

Resource Availability	Chandipur block
Resource by Storage	8.9064

Table 9.8 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in (m^2/day)	Annual Flow in MCM
Chandipur	15.00	0.000300	2000.00	3.29

9.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from Tertiary aquifers the following chemical parameters are detected in Chandipur block.

Table 9.9 Results of Chemical analysis of Tertiary aquifer in Chandipur

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO_3	HCO_3	TA as CaCO3	Cl	SO_4	NO_3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO_4	Fe
1	Muradpur	Chandipur	Tertiary	8.15	1161	bdl	329	270	178	52	15	50	9	225	152	23.4	0	2.25
2	Ersal	Chandipur	Tertiary	8.24	1111	bdl	378	310	142	14	21	38	2	150	173	15.6	0	0.27
3	Rasikchak	Chandipur	Tertiary	7.8	1021	bdl	67	372.1	121	16	9.5	54	5	155	154	8	1.7	bdl
4	Kotbar	Chandipur	Tertiary	7.92	1078	bdl	250	372.1	128	32	22	54	9	170	161	12	1.9	bdl

The water from Tertiary is fresh and the EC varies between 1000-1200 **µS/cm**. The concentration of Fe in ground water is reported high in Muradpur. The water is mostly sodium chloride and sodium bi-carbonate water.

9.8 Ground Water Resource Enhancement and Management Plan:

9.8.1 Ground Water Management Plan for drinking purposes

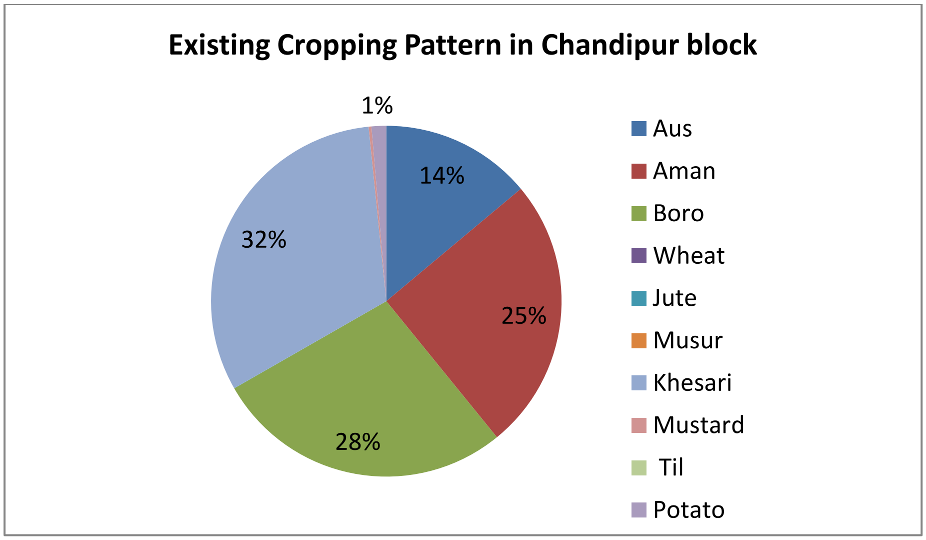
PHED, Govt. of West Bengal is entrusted for supply of drinking water in the block. Besides spot sources of hand pumps, mark II tube wells PHED has so far commissioned 5 no ground water-based water supply schemes and 3 more ground water based schemes are under commissioning in the block. Besides that, a surface water-based schemes have been designed for the population of Nandigram I& II, Chandipur and Nandakumar block. It has been assessed that total covered population through the commissioned schemes is about 99725. Therefore, 88494 remaining population need to be brought under water supply schemes for which about 1.2920 MCM water is required. As per the prevailing practices in the block the Tertiary aquifer may be utilized to cater the remaining need of drinking water supply in the block. Thus, 7 drinking water tube wells in Tertiary aquifer may further be constructed in phases to meet the demand from ground water resources. Therefore, further development of this aquifer will definitely affect the ground water regime in the area. It is estimated that the probable decline of piezometric surface in Tertiary aquifer an impact of installation of additional tube wells would be 13.5-14.00 m. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation should always be compensated by construction of suitably design artificial recharge structures in respective aquifers.

Table 9.10 Development Proposal of Tertiary Aquifers with implication on Piezometric Surfaces of Each Aquifer

Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncovered population @40lpcd in MCM	Annual resource proposed to be utilized from Quaternary Aquifer in MCM	Annual resource proposed to be utilized from Tertiary Aquifer in MCM	Total annual unit draft of one TW in MCM (considering average discharge of Quaternary and 8 hrs/day running)	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary and 8 hrs/day running)	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquifer	Decline of piezometric surface in Quaternary Aquifer (in m)	Decline of piezometric surface in Tertiary aquifer(in m)
Chandipur	137.58	1.2920	0.0000	1.2920		0.1752	0	7		13.81

9.8.2 Management Plan for irrigation:

Present cropping pattern in the block: The major crop in the block includes Aman and Aus paddy, Boro paddy and Khesari. Boro is 28% of the total crop in the block. Other includes little mustard and potato.



The cultivable area of the block is 10430 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA in the block is 12099 ha which exceeds the total cultivable area in the block. Therefore, additional irrigation potential is only required to bring further area under cultivation by suitable modification or for diversification of crops in the block.

The quaternary aquifer in the block is reported to be brackish to saline in nature and in general not developed at all for irrigation uses. Tertiary aquifers in the block are under semi confined to confined condition and witnesses steady decline of water level therefore, further development of irrigation tube wells is not recommended. In contrary to these the trivial modification of cropping pattern may bring more area under irrigation in the blocks or can pave the scope for cultivation of alternative crops. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 295.20 ha m of water. This volume of water is used to cultivate oilseeds (sunflower/ mustard, pulses, potato etc. as per the prevailing cropping pattern in the block. Thus, 491 ha effective increase in irrigation area may be created by change in cropping pattern. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability.

Table 9.11 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation				Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction(ha)	Volume of Irrgation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor:30 cm)	Potato (Delta factor:60 cm)	Total additional area created in ha	Effective Increase in area(ha)
Chandipur	2462	1.2	2216	295.20		245.75	327.67	163.84	737.26	491.06

9.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non-committed surface runoff produced in the block is 21.1163 MCM. The non-committed flow is proposed to be utilized to recharge the depleted Tertiary aquifers in the block. As per the available storage space 0.9208 MCM water is required to fill the available storage space in tertiary aquifers in block. Therefore, 69 injections well with roof top rainwater harvesting structures are recommended in the block. The successful implementation of recharge structures may raise the piezometric surface about 9-10 m. Further, in case of construction of more tube wells in Tertiary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated.

The remaining non committed runoff, 20.1955 MCM is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 404 storage tanks have been proposed. These tanks can generate additional irrigation potential of 3029.33 ha considering average delta factor of 50 cm for rabi crops, vegetable, horticulture/ floriculture crops or the storage tanks may be utilized for other purpose like pisciculture etc. The roof top rainwater harvesting structures with suitably design injection wells may be proposed to construct in the census town area in primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with 1-2 irrigation tanks for harvesting of surface runoff at suitable locations and for subsequent irrigation/aquaculture uses.

Table 9.12 Proposed Conservation and Recharge Structures based on the available non committed surface runoff and available storage space

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Vol of water kept for conservation/storage tanks in MCM	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary	No of RTRWH with injection well required for Quaternary
Chandipur	137.58	21.1163	0.9208		20.1955		404	0.0133072	69	

Summary of Management Plan:

- Drinking water tube wells have been recommended in Tertiary aquifer to meet the uncovered demand from ground water sources. 7 drinking water tube wells in Tertiary have been proposed.
- The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of 69 injection wells in block with roof top harvesting arrangements.
- Further construction of irrigation tube wells is restricted. The boro area may be reduced by 10% of existing area, and the surplus water may be used to irrigate pulses, oilseed and potato for more diversification of crops. Thus additional 491 ha irrigation potential can be generated.
- The non-committed runoff may be harvested for storage tanks. Considering capacity of one tank as 0.05 MCM, 404 tanks are proposed, preferably one- two in each habitation in the block. This may generate additional irrigation potential of 3029 ha. Or the tanks may be utilized for aquiculture activities.

10.0 MANAGEMENT PLAN OF HALDIA AND SUTAHATA, BLOCKS

10.1 Location, Demography and Rainfall

Haldia block is located at 22.03 °N latitude and 88.06 °E longitude. The block is bounded in the east and north Sutahata and Mahisadal blocks of Purba Medinipur district respectively, Haldia Municipality and Bay of Bengal in the south and byHaldi River in the east.

Subdivision:Haldia

- **Sub basin: Rupnarayan and Haldi**
- Geographical Area: 65.44 sq km.
- Entire blocks under Rural area, there is no census town in the block.
- Population (2011 Census): 97,992
- **Haldia Municipality:**
- Area: 109.65 sq km
- Population: 2, 00,827
- Located in the south of Haldia block and facing Bay of Bengal at its south.

Block : Sutahata

Sutahata block is located at 22.140 °N latitude and 88.080 °E longitude Sutahata block is bounded in the east by Rupnarayan river and Bay of Bengal in the north by Mahisadal block in the west by Haldia block and its south Haldia Municipality and Bay of Bengal.

- Geographical Area: 79.54 sq km
- Population (2011 Census): 1, 23,784
- Population (2011 Census)

Table 10.1 Total population of the Blocks

Block	Rural Population	Urban Population	Total
Haldia		97992	97992
Sutahata	118629	5155	123784

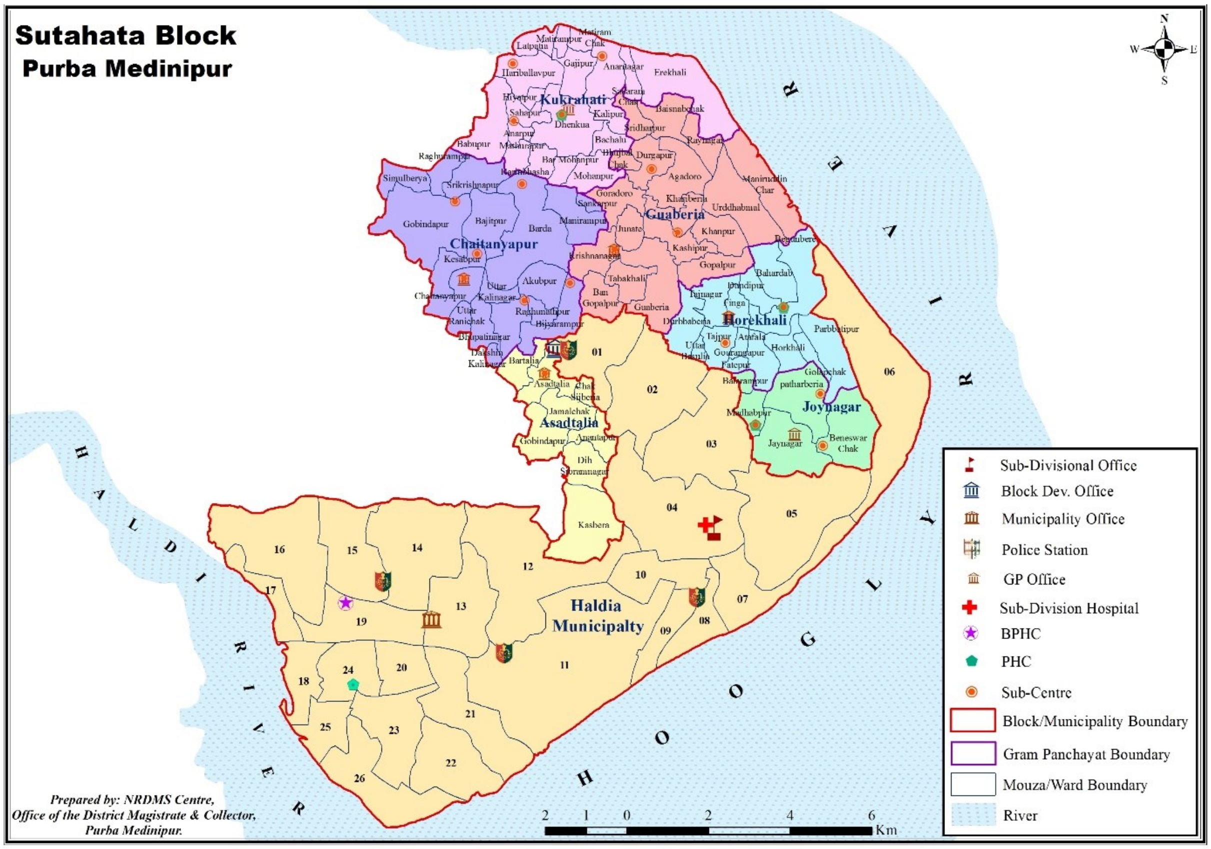


Figure 10.1 Gram-Panchayet and Mouza Map of Sutahata Block and ward map of Haldia Municipality

The Sutahata block comprises 1 census town, 6 Gram Panchayets, 78 villages, 176 habitations and 26936 households. The Haldia block comprises 4 Gram Panchayets, 24 villages, 91 habitations and 22,385 households

Table 10.2 Basic Demographic Detail of Sutahata block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	HouseHolds	Population
1	Asadtalia	7	17	1581	7282
2	Chaitanyapur	17	39	6782	31183
3	Guaberia	18	32	5790	27229
4	Horekhali	14	32	4961	23224
5	Joynagar	5	13	2335	10792
6	Kukrahati	19	44	5442	24617
	Total	80	177	26891	124327

Source: PHED, Govt. of WB, Website

Table 10.3 Basic Demographic Detail of Haldia block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	HouseHolds	Population
1	Baruttarhingly	8	32	6717	29502
2	Chakdwipa	3	17	4837	21634
3	Debhog	4	15	3481	15163
4	Deulpota	7	27	6473	28582
	Total	22	91	21508	94881

- **Normal Annual Rainfall** in the district: 1663.40 mm

Table 10.4 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall
Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

10.2 Physiographic and Drainage:

The blocks are a part of lower Gangetic plain and are part of Rupnarayan and Haldi sub basin. Both Rupnarayan and Haldi river meets Bay of Bengal in the southern parts of Haldia and Sutahata block. The drainage networks in the area are influenced by tidal effects. The tributaries of Rupnarayan also constitute the drainage volume of the block. Average elevation is 2-7 m amsl. The dominant soil type of the area very poorly drained impermeable clayey soil. The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

10.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 10.5 Details of Land use pattern of block (area in ha)

Name of the block	Reporting area	Forest area	Area under non-agriculture wastes	Barren and un-culturable lands	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Net area sown

Sutahata	16627	0	10815		2	58				5762
Haldia	11379	161	6332		1	49				4836

10.4 Agriculture and Irrigation:

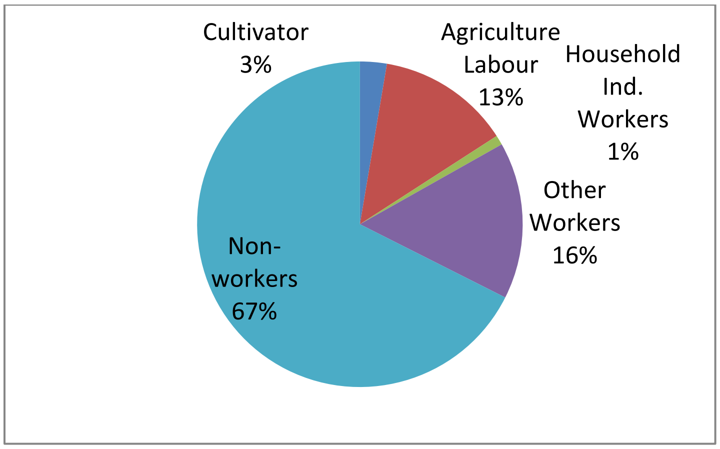


Figure 10.2 Distribution of persons engaged in agriculture and other workers/non workers in Sutahata Block

In Sutahatablock, 67% of total population is non workers. It is evident from the above diagram that only 16% of the total workers in the block are engaged in agriculture either as cultivator or as agriculture labour. 3% comprises Household industrial workers and 16% comprises other worker.

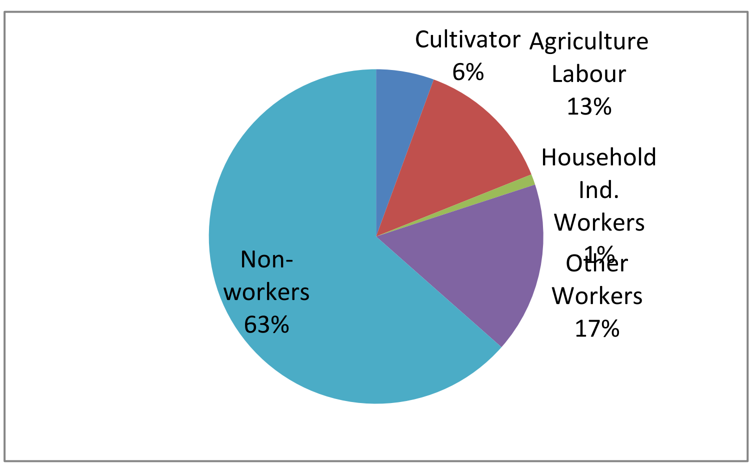


Figure 10.3 Distribution of persons engaged in agriculture and other workers/non workers in Haldia Block

In Haldia block, 63% of total population is non workers. It is evident from the above diagram that only 19% of the total workers in the block are engaged in agriculture either as cultivator or as agriculture labour. 1% comprises Household industrial workers and 17% comprises other worker.

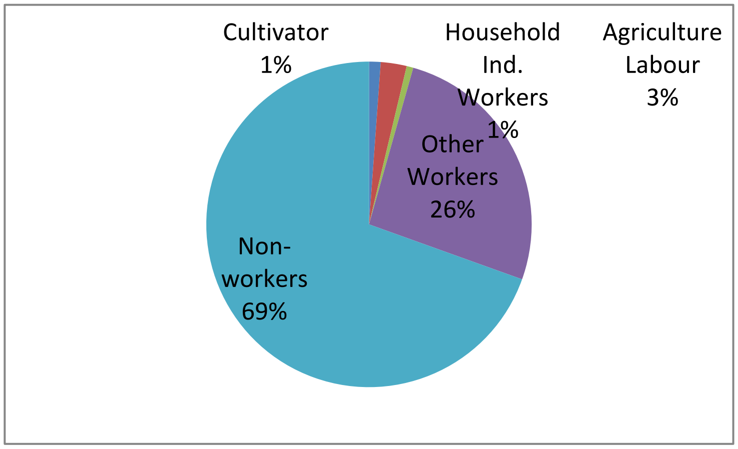
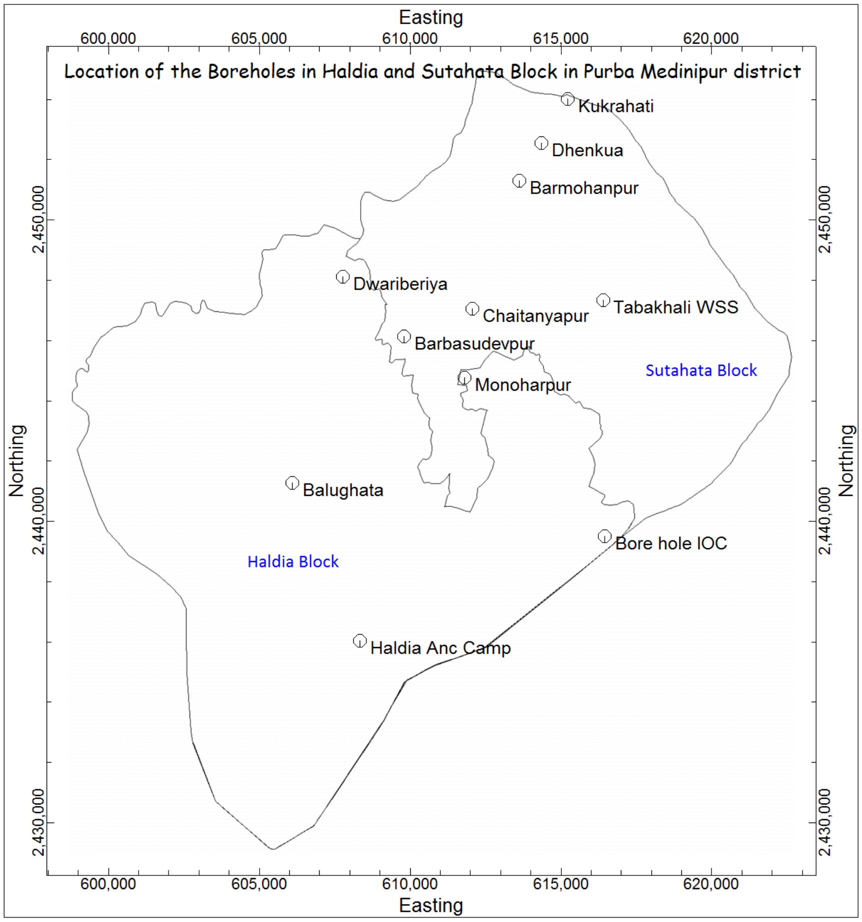


Figure 10.4 Distribution of persons engaged in agriculture and other workers/non workers in Haldia Municipal Area

In HaldiaMunicipal area , only 4% of the population are engaged in Agriculture activity, on the other hand House hold , industrial and other workers constitute 27% of the population. Irrigation in the blocks is achieved by surface and ground water sources. The Culturable Command area (CCA) created by surface water resources constitute 98% of the total CCA in Sutahata block.Ground water irrigation coverage is negligible.3329ha area has been brought under CCA by surface and ground water irrigation network**.**In Haldia block Culturable Command area (CCA) created by surface water resources constitute 94% of the total CCA in the block. Ground water irrigation coverage is negligible. 2680 ha area has been brought under CCA by surface and ground water irrigation network. The cultivable area in Sutahata and Haldia block is 5820 ha and 4885 ha respectively.

Surface irrigation network comprises tanks, surface flow and lift irrigation. As per the District Statistical Handbook, 2014,canal network is reported in Haldia block only. Both surface and ground water irrigation networks are not well developed in the blocks. Few tank irrigation have been recorded. In Haldia block 1378 ha canal area has been reported.

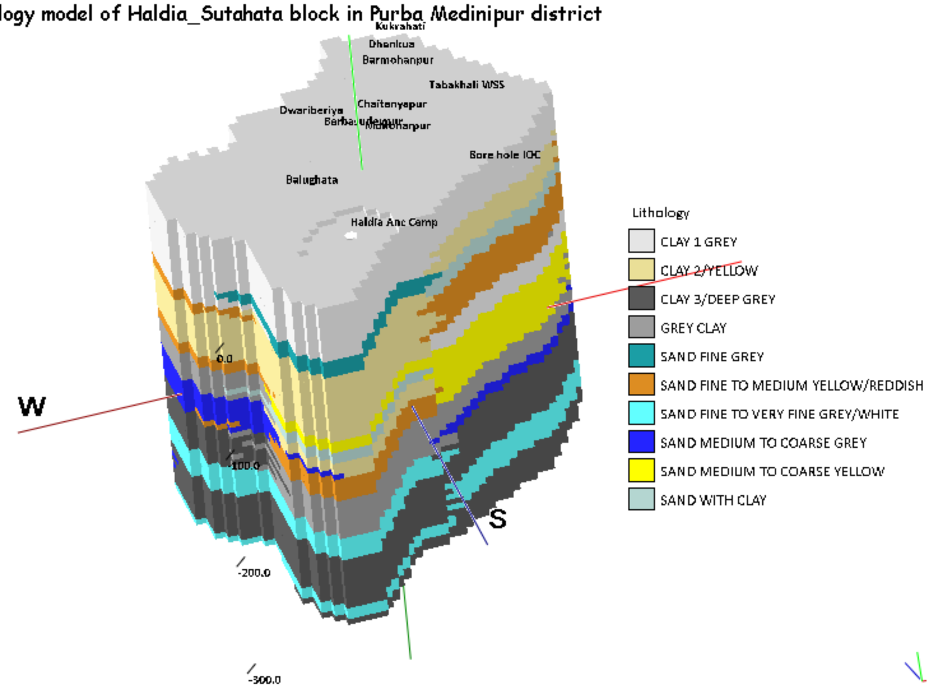
Ground water irrigation is limited and is not developed in both these blocks.

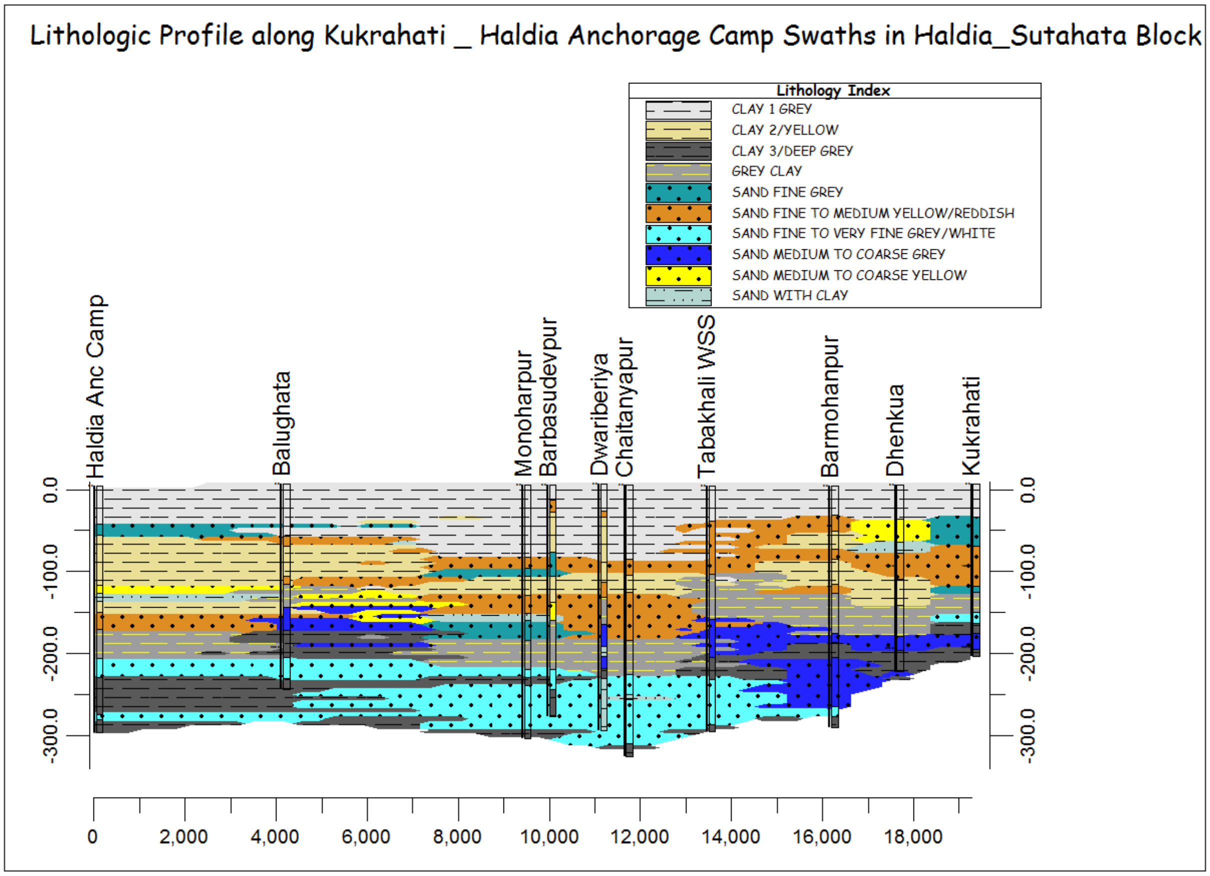


10.5 Geology and Sub-Surface Geology

The blocks are underlain by Quaternary sediments of Holocene and Pliestocene age. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt.Departments, theactual lithology and interpreted aquifer models are prepared and aquifer systems has been classified.

Lithology model of Haldia_Sutahata block in Purba Medinipur district





The lithology model reveals that the Haldia and the Sutahata blocks including the Municipal area is overlain by thick consistent surface clay. The surface clay is mostly gray in colour representing younger alluvium. The thickness of the surface clay varies between 40-60 m. The lithology is represented by alternate sequence of sands of fine to medium and coarse and clay. The younger alluvium is underlain by fine to medium yellow or brown coloured older alluvium sands separated by clay lenses. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and tertiary boundary is marked by occurrences of thick gray clay. Tertiary gray clay is thick and consistent and is found to occur at an average depth of 160 mbgl. The depth of occurrences of Tertiary clay varies in the blocks. The average thickness of the Tertiary clay is 30 m. Below the gray tertiary clay fine to medium grained grayish white sands of considerable thickness alternating with intervening clay constitute the Tertiary sedimentation within the explored depth.

10.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:

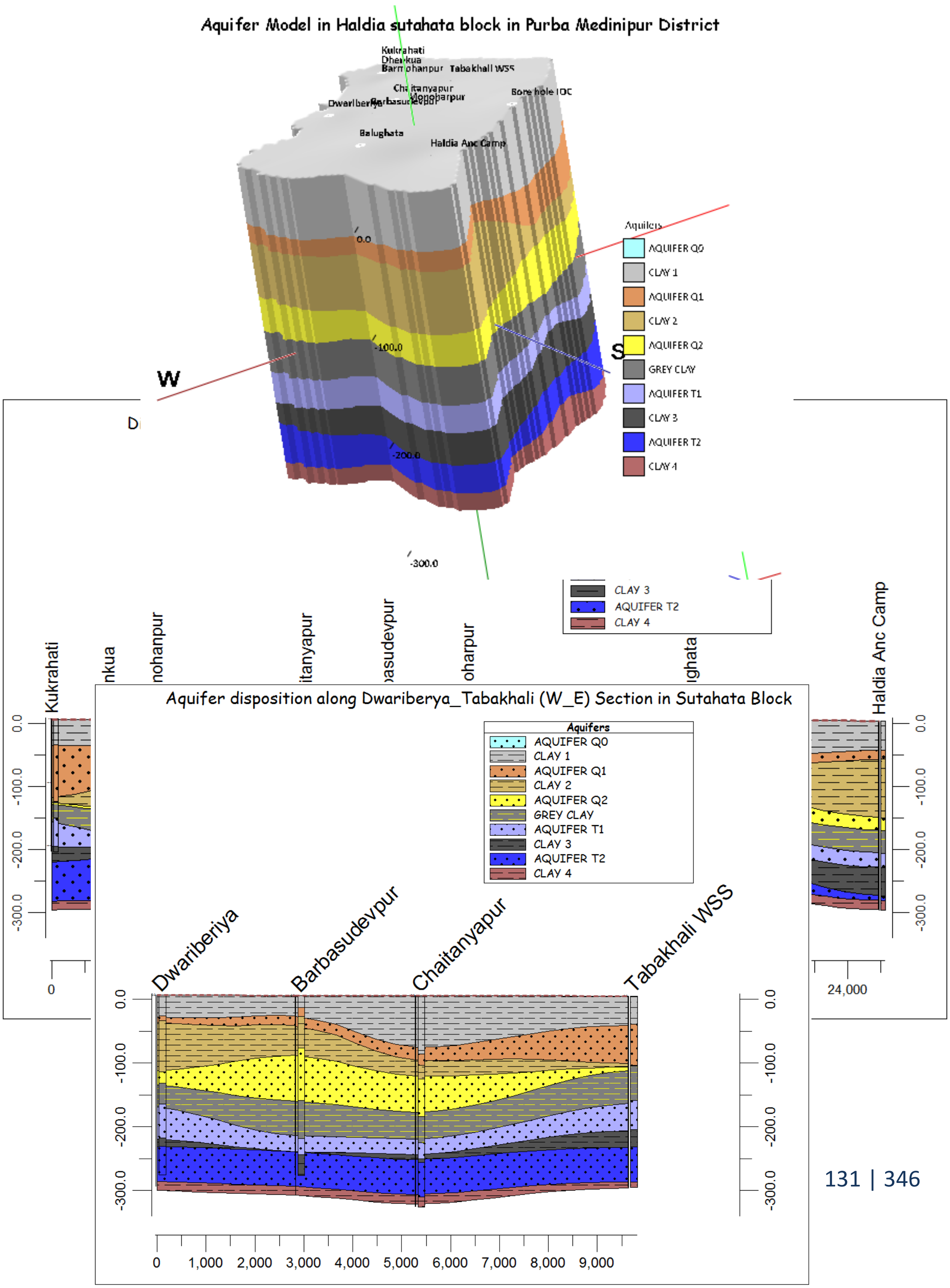


Table 10.6 Disposition of Aquifers and Q/T Boundary in Haldia-Sutahata area

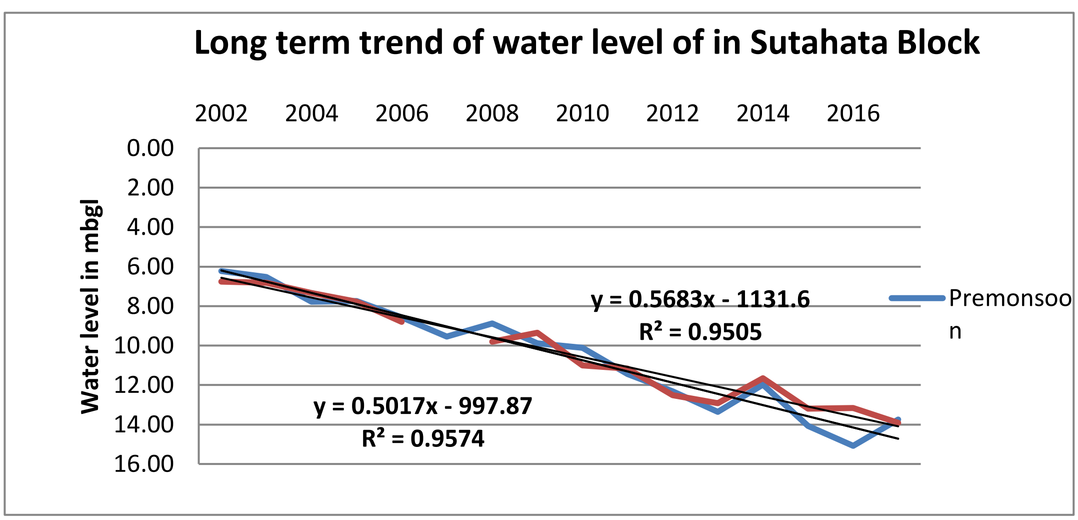
Block	Quaternary Aquifers						Q/T Boundary			Tertiary Aquifers					
	Q1			Q2						T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Haldia and Sutahata	52.24	86.25	34.01	121.61	160.53	38.91	160.53	189.81	29.38	183.27	217.09	33.82	241.38	283.38	42.00

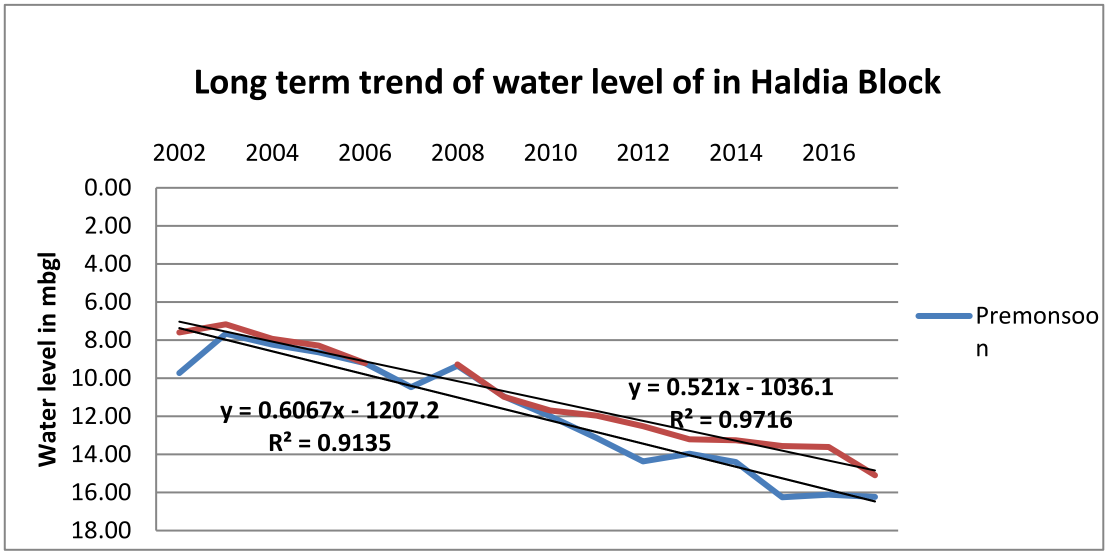
The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. The cumulative thickness of Quaternary and Tertiary aquifer in the area is about 70-80 m. Both the Quaternary aquifers are found to occur throughout the area. The Q/T boundary is very distinctive and is marked by thick persistent gray clay throughout the area. The undulatory nature of the layers indicates uneven or the undulation in the basin of sedimentation. The separating clay between two Tertiary aquifers (T1 and T2) is present throughout the block thus, T1 and T2 represent two aquifers within the Tertiary. The Tertiaries are thick and potential with minor variation in the thickness across the block. The T1 and T2 almost converges to form single Tertiary aquifer around Chaitnyapur, Barbasudevpur and Monoharpur area.

Ground water condition

Groundwater, in both quaternary and tertiary aquifer system is undersemi-confined to con fined condition. Pre and post monsoon water level have been monitored from number of observation wells (200-300 m depth)in Tertiary aquifer systems. Due to the paucity of the working tube wells in the quaternary aquifer, the monitoring data from the quaternary aquifer was limited. The piezometric water level data of CGWB and SWID has been compiled and long term water level 2002-2017 has been analysed from SWID data for Tertiary aquifer only. It is observed that Tertiary registers a long term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow from NW-SE. However, the flow pattern in the block is influenced by the development around Haldia Municipal area and Sutahata block and thus forms local troughs. The piezometric surface has gone down about 16.5 m below msl in the area.

Block	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m below msl)
Haldia	14	11-20.5	13-19.5	46cm fall	39 cm fall	-3.8 to -14.20
Sutahata	14	14-20	12-14	60 cm fall	52 cm fall	-6.5 to -16.5





Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is high about 65-140 m^3/hr with moderate drawdown of below 6 m.The specific capacity ranges between 19-42 m^3/hr/m drawdown.

***Aquifer* Wise Ground Water Resource Availability**

The aquifer which is proficiently developed in theseblocks is the Tertiary aquifer. The Tertiary aquiferis in semi-confined to confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl, therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area.

Table 10.7 Details of resource available in Tertiary aquifer (in MCM) in Blocks

Resource Availability	Sutahata	Haldia	Haldia

			Municipality
Resource by Storage	9.0434	7.4180	12.4295

Table 10.8 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in (m^2/day)	Annual Flow in MCM
Sutahata	11.67	0.000563	2000.00	4.79
Haldia	15.00	0.000500	2000.00	5.48

10.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from Tertiary aquifers the following chemical parameters are detected in Sutahata and Haldia block

Table 10.9 Results of Chemical analysis

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO_3	HCO_3	TA as CaCO3	Cl	SO_4	NO_3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO_4	Fe
1	haldia township	Haldia	Quaternary	7.82	1710	bdl	409	335	338	38	10	6	2	280	248	50.7	1.6	9.14
2	barsunda	Haldia	Tertiary	7.63	1597	bdl	122	384.3	277	55	42	44	23	205	230	70	0	bdl
3	solat	Haldia	Tertiary	8.16	3742	bdl	275	1091.9	658	22	18	266	9	700	490	101	6.3	0.33
4	mohonpur	Haldia	Tertiary	8.17	1424	bdl	214	384.3	249	11	6.3	66	9	200	198	43	9.1	4.31
5	dwariberia	Haldia	Tertiary	7.94	1308	bdl	61	463.6	178	16	10	56	5	160	214	23	3.4	bdl
6	balughata primary school	Haldia	Tertiary	8.18	1739	bdl	311	378.2	324	64	40	64	10	200	276	51	5.7	1.13
7	dhenkua	Sutahata	Tertiary	7.96	1093	bdl	183	390.4	139	21	5	56	2	150	166	23	4.7	bdl
8	asadtalia	Sutahata	Tertiary	8.1	1352	bdl	85	402.6	231	25	8.2	8	4	35	278	35	1.6	0.94
9	chaitanyapur zone II bhupatinagar	Sutahata	Tertiary	8.2	1481	bdl	128	433.1	267	8	12	46	12	165	258	55	1.7	1.95
10	basudevpur high school	Sutahata	Tertiary	7.83	1445	bdl	128	274.5	284	75	20	54	6	160	248	39	3.5	6.91
11	hokhali	Sutahata	Tertiary	7.72	972	bdl	73	298.9	121	52	14	32	7	110	161	20	4.1	0.32

The water from Tertiary is fresh to brackish in nature. The EC value reported at Solat Water Supply Schemes is quiet high, which may be due to contamination of Tertiary aquifer in the area due to percolation and mixing of saline quaternary aquifer to the Tertiary aquifer at that particular well. Fe is reported higher in number of occasions. The water is mostly sodium chloride and sodium bi-carbonate water.

10.8 Ground Water Resource Enhancement and Management Plan:

10.8.1 Ground Water Management Plan for drinking purposes

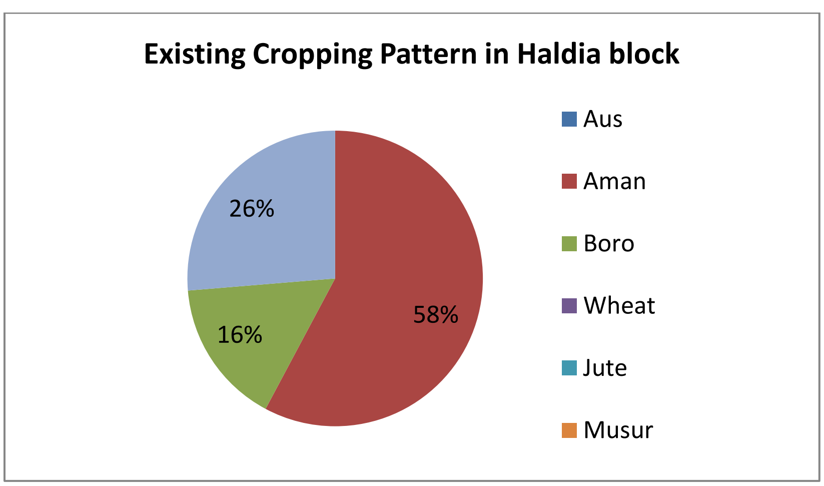
PHED, Govt. of West Bengal is entrusted for supply of drinking water in these blocks. Besides spot sources of hand pumps, mark II tube wells, PHED has so far commissioned 7 no ground water based water supply schemes in Haldia block and 4 no ground water based schemes in Sutahata block. Few of these schemes have been subsequently augmented. It has been assessed that tentative covered population through these schemes is 136511 in Haldia and 97614 in Sutahata block. Therefore, 162308 remaining population in Haldia block need to be brought under water supply schemes for which about 2.3697MCM water is required. On the other hand, in Sutahata block 26211 remaining population need to be brought under water supply schemes for which about 0.3812MCM water is required. The Tertiary aquifers in these blocks are meant to supply drinking water in these blocks. Thus, 13 drinking water tube wells in Haldia block and 2 tube wells in Sutahata block may further be constructed in phases to meet the demand from ground water resources. Further development of this aquifer will definitely affect the ground water regime in the area. It is observed that the probable decline of piezometric surface in Tertiary aquifer in Haldia area would be 19 m whereas in Sutahata would be 7 m. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation should always be compensated by construction of suitably design artificial recharge structures in respective aquifers.

Table 10.10 Development Proposal of Tertiary Aquifers with implication on Piezometric Surfaces of Each Aquifer

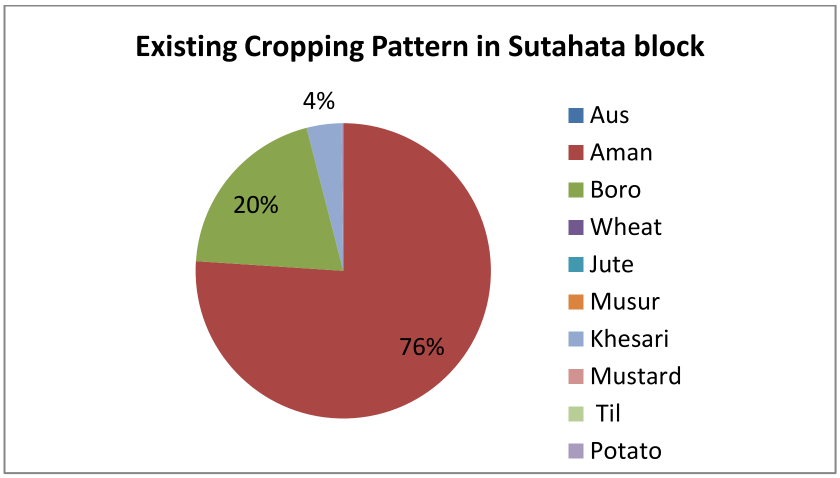
Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncovered population @40lpcd in MCM	Annual resource proposed to be utilized from Quaternary Aquifer in MCM	Annual resource proposed to be utilized from Tertiary Aquifer in MCM	Total annual unit draft of one TW in MCM (considering average discharge of Quaternary and 8 hrs/day running)	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary and 8 hrs/day running)	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquifer	Decline of piezometric surface in Quaternary Aquifer (in m)	Decline of piezometric surface in Tertiary aquifer(in m)
Haldia	65.44	2.3697	0.0000	2.3697		0.1752	NA	13	NA	19.9
Sutahata	79.54	0.3812	0.0000	0.3812		0.1752	NA	2	NA	7.05

10.8.2 Management Plan for irrigation:

Present cropping pattern in Haldia block: The crop grown statistics in Haldia Block shows that the no major crops are grown in profusion in the block. The aman paddy is the maximum in 1571 ha area and constitute 58% of total cropped area. The other includes boro in 16% area and Khesari in 26% area .No other major crops are recorded from the block. Brackish to saline ground water and tidal influence in river or khal water impedes irrigation development in the block.



Present cropping pattern in Sutahata block: The crop grown statistics in Sutahata Block shows that the no major crops except aman rice are grown in profusion in the block. The aman paddy is the maximum in 4596 ha area and constitute 76% of total cropped area. The other includes boro in 20% area (1206 ha) and Khesari in 4% area. No other major crops are recorded from the block. Brackish to saline ground water and tidal influence in river or khal water impedes irrigation development in the block



The cultivable area of the Haldia block is 4885 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA in the block is 2679.50 ha. Further, 2205 ha area is to be brought under irrigation coverage in the blocks. The irrigation tube wells are not very common in the block.

The cultivable area of the Sutahata block is 7954 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA in the block is 3329 ha. Further, 2491 ha area is to be brought under irrigation coverage in the blocks. The irrigation tube wells are not very common in the block.

The available resource both in Quaternary and Tertiary aquifer in both the blocks are limited and the Quaternary aquifer is reported with brackish to saline water. Tertiary aquifers are under semi confined to confined condition and witnesses steady decline of water level, therefore, further development of irrigation tube wells is not recommended. In contrary to these the trivial modification of cropping pattern may brought more area under irrigation in the blocks, therefore increases the intensity of cropping. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 51.60 ha m of water in Haldia block and 145.20 ham of water in Sutahata block. This volume of water is used to cultivate pulses etc. as per the prevailing cropping pattern in the block. Thus, 14.08 ha in Haldia block and 40.57 ha in Sutahata block effective increase in irrigation area may be created by change in cropping pattern. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability.

Table 10.11 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation				Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction(ha)	Volume of Irrgation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor:30 cm)	Potato (Delta factor:60 cm)	Total additional area created in ha	Effective Increase in area(ha)
Haldia	432	1.2	389	51.60			57.28	--	57.28	14.08
Sutahata	1206	1.2	1085	145.20			161.17		161.17	40.57

10.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non-committed surface runoff produced in Haldia block is 10.0440 MCM and in Haldia Municipal area is 16.8295 MCM, on the other hand the runoff produced in Sutahata block is 12.2081 MCM. The non-committed flow is proposed to be utilized to Tertiary aquifers in the blocks. As per the available storage space 0.4678 MCM and 0.7838 MCM water in Haldia block and Municipality respectively is required to fill the available storage space in tertiary aquifers. Therefore, 35 injection wells with roof top rain water harvesting structures is recommended in Tertiary aquifer in Haldia block and 59 injection well in Haldia Municipal area. Similarly, in Sutahata block to fill the available storage space with 0.5237 MCM of water 39 injection wells are recommended. The successful implementation of recharge structures may raise the piezometric surface in the above area to the extent of 9.5 m to 10.50 m. Further, in case of construction of more tube wells in Tertiary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated.

The remaining non committed runoff, 9.5762 mcm in Haldia block is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 192 storage / irrigation tanks have been proposed. Thus, in Sutahata block the remaining non committed runoff of 11.6844 mcm of water may be utilized for generation of irrigation potential by construction of 234 storage tanks. These tanks can generate additional irrigation potential of 1436 ha in Haldia block and 1753 ha in Sutahata block considering average delta factor of 50 cm for pulses, rabi crop, vegetables, etc. Therefore, by change in cropping pattern and utilizing the non-committed runoff throghr tank irrigation total 1450.50 ha additional irrigation potential can be created in Haldia which accounts for 66% coverage in the remaining area where irrigation facilities were to be extended. In Sutahata block 1793.23 ha additional irrigation potential may be created which accounts for 72% coverage wrt the remaining area. The roof top rain water harvesting structures with suitably design injection wells may be proposed to construct in the urban area/census towns in primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with 1-2 irrigation tanks for harvesting of surface runoff at suitable locations and for subsequent irrigation uses.

Summary of Management Plan:

- *Drinking water tube wells have been recommended in Tertiary aquifer to meet the uncovered demand from ground water sources. Thus, 13 tube wells in Haldia block and 2 tube wells in Sutahata block are recommended.*
- *The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of 35 injection wells in Tertiary aquifer in Haldia block and 39 injection wells in Sutahata block. With the surplus available runoff 59 injection wells may be recommended in Haldia Municipal area. The construction of injection wells should be accompanied with suitable designed roof top rainwater harvesting structures and may be constructed in phases as per the situation.*
- *Further construction of irrigation tube wells is restricted. The boro area may be reduced by 10% of existing area, and the surplus water may be used to irrigate pulses, etc. Thus, few additional irrigation potentials can be generated.*
- *The non-committed runoff may be used for irrigation tanks. Considering capacity of one tank as 0.05 MCM, 192 irrigation tanks are proposed in Haldia block and 234 irrigation tanks are proposed in Sutahata block, preferably one- two in each habitation in the blocks. This will generate additional irrigation potential of 1436 ha and 1753 ha respectively. Thus, the additional irrigation potential created by change in cropping pattern and by harvesting surface runoff will bring 66-72% of the remaining cultivable area in the block under irrigation coverage.*

Table 10.12 Proposed Conservation and Recharge Structures based on the available non committed surface runoff and available storage space

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Vol of water kept for conservation/storage tanks in MCM (3-(4+5))	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks (6/8)	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary (4/9)	No of RTRWH with injection well required for Quaternary (5/9)
1	2	3	4	5	6	7	8	9	10	11
Haldia	65.44	10.0440	0.4678		9.5762	0.05	192	0.0133072	35	
Sutahata	79.54	12.2081	0.5237		11.6844	0.05	234	0.0133072	39	

11.0 MANAGEMENT PLAN OF KHEJURI II BLOCK

11.1 Location, Demography and Rainfall

Khejuri II is located at 21.8575°N latitude and 87.9115 °E longitude Bounded in the north by Nandigram I block , Deshopran block in the south, in the west by Khejuri I block and in the east and south east by Bay of Bengal. The Rasulpur River is flowing along the south west boundary of Khejuri II block.

- Subdivision: Contai
- Sub basin: Keleghai-Haldi
- Geographical Area: 137.46 sq km
- Population (2011 Census)

Table 11.1 Total population of the Block

	Rural Population	Urban Population	Total
Block	139463	---	139463

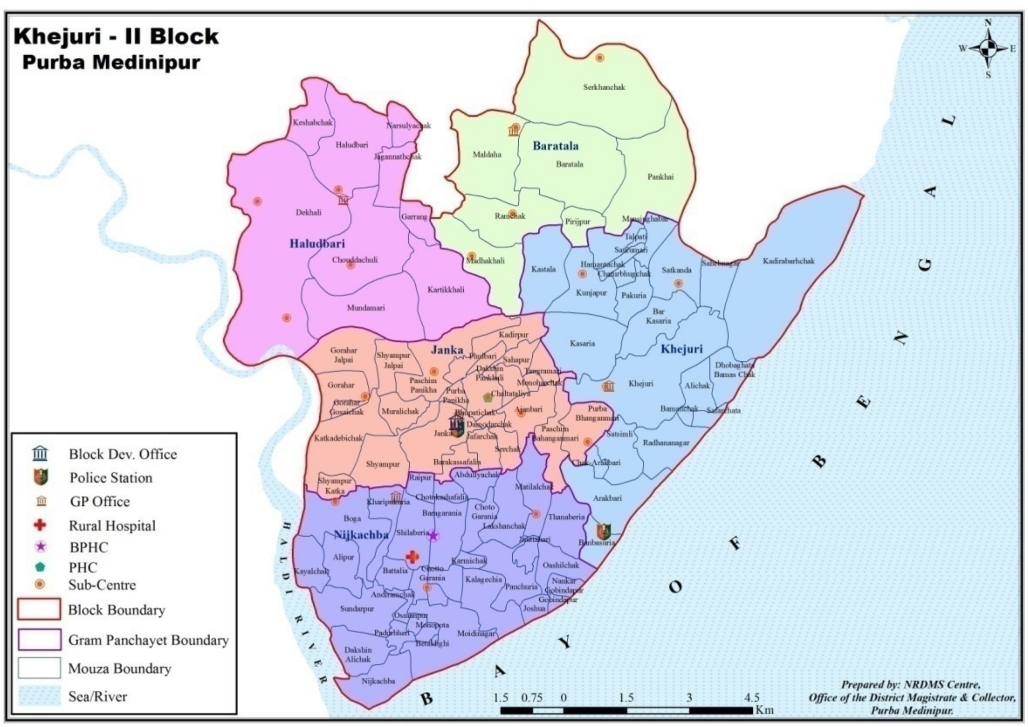


Figure 11.1 Gram-Panchayet and Mouza Map of Khejuri II Block

The block comprises 5 Gram Panchayets, 98 villages, one census town, 245 habitations and 27687 households.

Table 11.2 Basic Demographic Detail of Khejuri II Block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	House Holds	Population
1	Baratala	7	48	4978	25092
2	Haludbari	10	35	5480	27314
3	Janka	26	47	5634	29088
4	Khejuri	24	56	5655	30153
5	Nijkasba	31	59	5940	30524

Source: PHED, Govt of WB, Website

- **Normal Annual Rainfall** in the district: 1663.40 mm

Table 11.3 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall
Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

11.2 Physiographic and Drainage:

The block is a part of lower Gangetic plain and comprises coastal block in the State. Khejuri and Nijkasba GP of the block directly face Bay of Bengal. Rasulpur River is flowing in the south east direction along the southern boundary of Khejuri II block. Rasulpur River and other drainage channel in the area experiences tidal influences.

The dune sands in Khejuri area is east to east-south east continuation of arcuate sand ridges of Contai area. Occurrences of arcuate belts parallel to sub parallel existing coast line are very much conspicuous because of the deep dark vegetation cover. The belt is exactly matches with the inland Contai dunes when extends in the west. The number of small sandy ridges on otherwise silty-clayey tidal flats is the most interesting and important hydrogeomorphic units in the study area. The entire Khejuri village is on the dune itself; other villages on Dune sands in

Khejuri II blocks include Poduvery, Kunjapur, Nijkasba etc. The maximum height of this dune varies between 10-15 m. The average elevation in the block is 4 mamsl except the dune area.

The dominant soil type of the block is very poorly drained impermeable clayey soil except moderately drained and well drained soils are found along the river channels. The dune area is also characterized by occurrences of well drained sandy soil.

The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

11.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 11.4 Details of Land use pattern of block (area in ha)

Name of the block	Reporting area	Forest area	Area under non-agriculture wastes	Barren and un-culturable lands	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Net area sown
Khejuri II	13619	71	2718							10830

11.4 Agriculture and Irrigation:

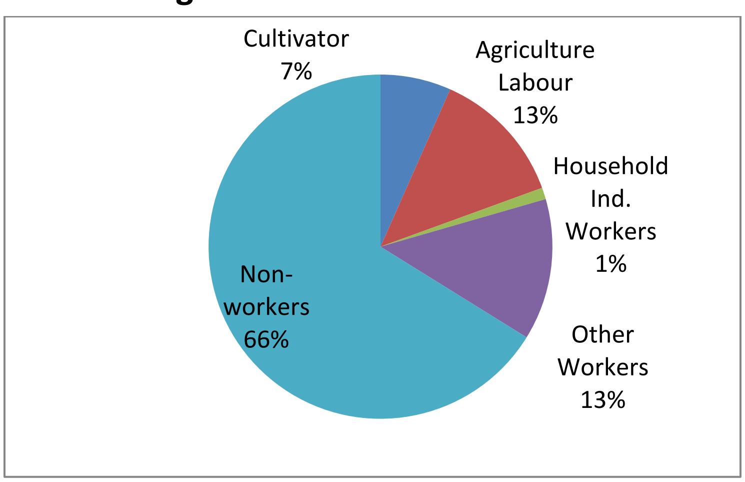


Figure 11.2 Distribution of persons engaged in agriculture and other workers/non workers in the Block

In Khejuri II block, 66% of total population is non workers. It is evident from the above diagram that 20% of the total population is engaged in agriculture either as cultivator or as agriculture labour. 1% comprises Household industrial workers and 13% comprises other worker.

Irrigation in the block is achieved by surface and ground water sources. The total cultivable area in the block is 10830 ha. The Culturable Command area (CCA) created in the block is only 1793 ha. Due to the brackish and saline nature of shallower aquifer and salinity in surface water very less irrigation command area has been generated so far in the block. Ground water resources constitute 64% of the total CCA in the block. Surface water irrigation coverage is 36% in the block.

Surface irrigation network comprises canal, tanks, surface flow and lift irrigation. A considerable area is brought under irrigation through tank irrigation. Surface flow, lift irrigation comprises other mode of surface irrigation networks in the block.

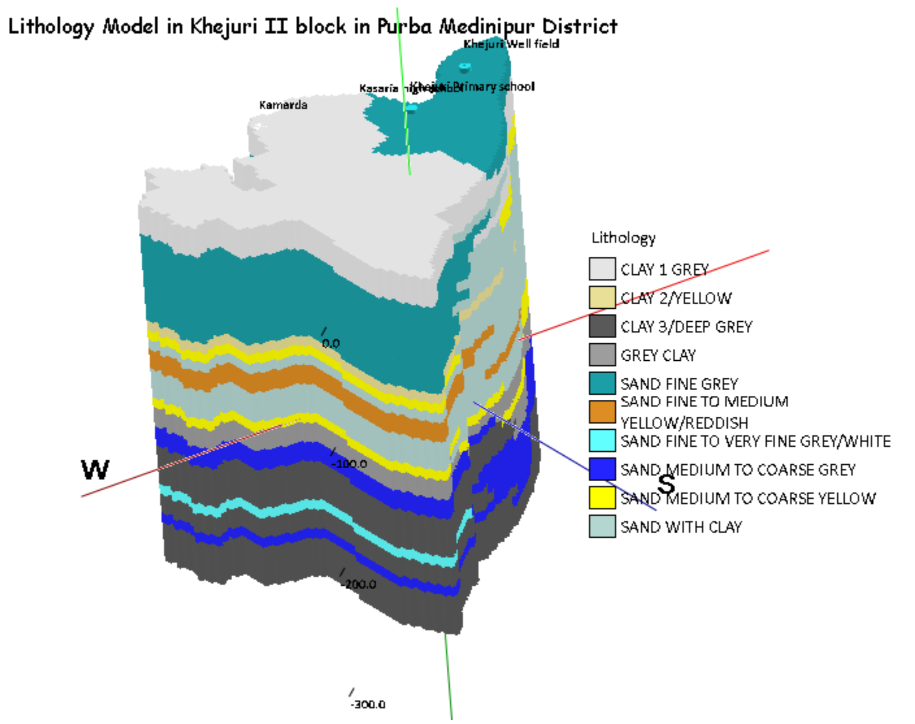
Ground water irrigation is accomplished mainly through shallow tube wells and medium tube wells. The CCA created by about 117 shallow tube wells is 600 ha and by 57 medium deep tube well 541 ha

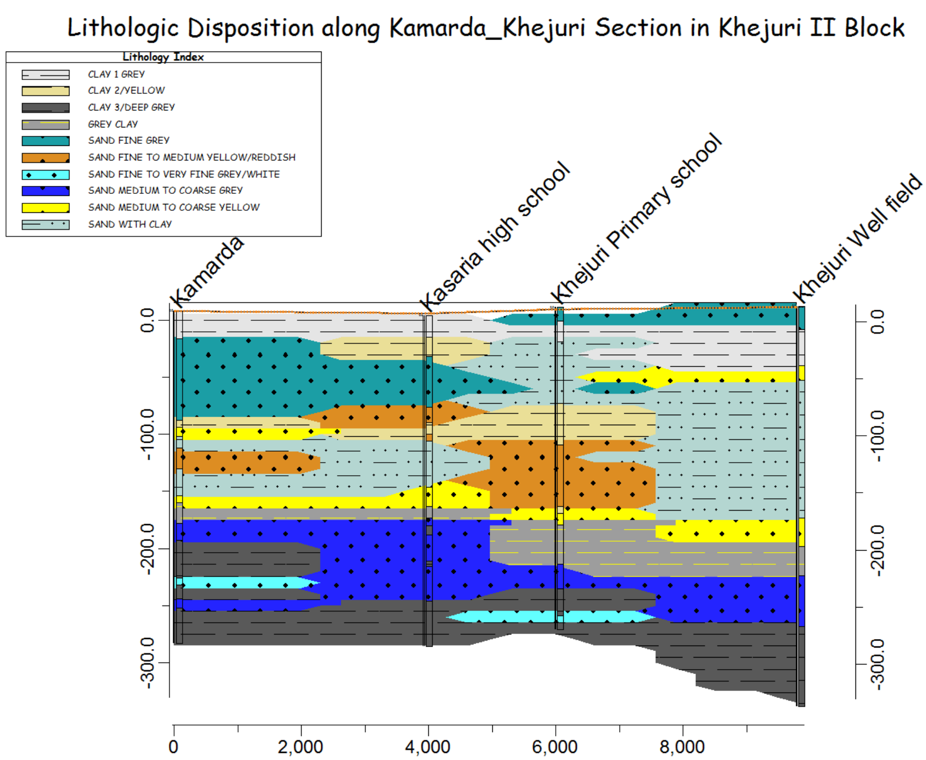
Table 11.5 CCA Created by Different Sources in the block (2013-14)

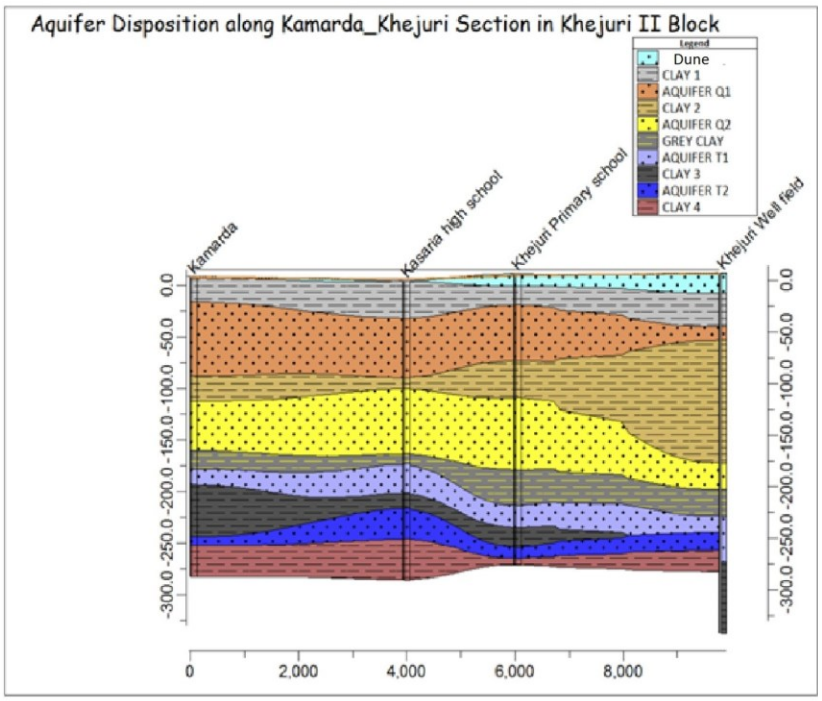
Block Name	Dugwell		Shallow Tubewell		Medium Tubewell		Deep Tubewell		Surface Flow		Surface Lift		CCA(ha.)		Total CCA(ha.)
	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	Ground Water	Surface Water	
Khejuri II	1.00	6.69	117.00	600.63	57.00	541.45	0.00	0.00	42.00	242.36	60.00	402.28	1148.77	644.64	1793.41

11.5 Geology and Sub-Surface Geology

The block is covered by Holocene sediments. The newer alluvium of Holocene age is underlain by Pleistocene Quaternary sediments. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt. Departments, the actual lithology and interpreted aquifer models are prepared and aquifer systems has been classified.







Lithology model reveals that the block is overlain by thick surface clay of 30-40 m thick. However, in the eastern and south eastern parts of the block in Khejuri, Nijkasba, Kunjapur villages fine to very fine recent sands of dune ridges overlies the tidal flats. The surface clay is mostly gray in colour representing younger alluvium. The lithology is represented by alternate sequence of sands of fine to medium and coarse, sandy clay and intervening Quaternary older alluvium clay. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and tertiary boundary is marked by occurrences of thick gray clay. Tertiary gray clay is thick (25 m) and consistent and is found to occur at an average depth of 190 mbgl. In Khejuri II block the cumulative thickness of Quaternary sediment is more than that of Tertiary sediments within the depth of 325 m.

11.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:

The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. The cumulative thickness of Tertiary aquifer in the area is less (35-40 m) than that of Quaternary aquifers (90-100 m) within the explored depth of 300 m. Both the Q1 and Q2 are fairly thick and consistent. Besides these two major aquifer systems in the area the dune sands of 10-20 m thick constitutes shallow phreatic aquifer in Khejuri, Nijkasba, Kunjapur etc.

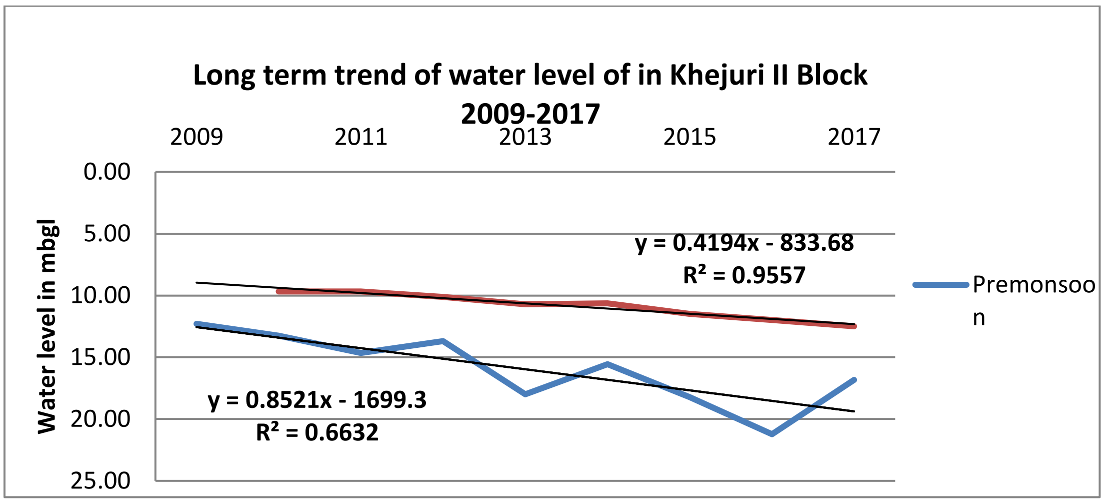
Table 11.6 Disposition of Aquifers and Q/T Boundary In Khejuri II Block

Block	Quaternary Aquifers						Q/T Boundary			Tertiary Aquifers					
	Q1			Q2						T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Khejuri II	35.33	81.67	46.33	141.67	189.33	47.67	189.33	215.67	26.33	215.67	242.33	26.67	258.50	268.00	9.50

Ground Water Condition

Groundwater, in both Quaternary and Tertiary aquifer system is under confined condition. Pre and post monsoon water level have been monitored from observation wells in Quaternary and Tertiary aquifer systems. The depth of the wells in Tertiary is 180-275 m. and in quaternary is below 100 m. The data of CGWB and SWID has been compiled and long term water level 2009-2017 has been analyzed from SWID data for Tertiary aquifer. It is observed that Tertiary registers a long term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow from NW-SE and NE-SW from 1 m below sea level to 4 m below sea level in Quaternary aquifer and 8 to 14.75 m below sea level in Tertiary aquifers. The ground water flow is influenced by local ground water development in the block and in surrounding area.

Aquifer system	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m below msl)
Tertiary	10	13-18	10.70-13.70	85	41	-8 m to-14.75m
Quaternary	2		8.00			-1 to -4 m



Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is about 108-111 m^3/hr with moderate drawdown. The CGWB exploration data reveals that the well of 111 m depth tapping 12 m granular zones in quaternary aquifer yield at 50 m^3/hr. The water level of the quaternary aquifer is also moderate within 8-10 mbgl. The specific capacity ranges between 20-35 m^3/hr/m drawdowns.

***Aquifer* Wise Ground Water Resource Availability**

The entire block, except the dune sand, is under confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl, therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area. The available resource both in Quaternary and Tertiary aquifers have been estimated separately. It has also been estimated that 3.65 MCM of water flows across the Tertiary aquifers in the block.

Table 11.7 Details of resource available in Khejuri II Block (in MCM)

Resource Availability	Tertiary in MCM	Quaternary in MCM
Resource by Storage	18.6011	2.3368

Table 11.8 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in ($m^{2/}$day)	Annual Flow in MCM
Khejuri II	20.00	0.000250	2000.00	3.65

Resource in Dune Sands in Khejuri II blocks

In addition to resource in confined aquifers the dynamic resource of separate hydrogeomorhic dune units has also been assessed.. 4 major dunes are identified in Khejuri II blocks. Maximum elevation of dune ridges 10-12 m amsl. The sands are fine grained with moderate to high infiltration capacity. The each dune serves as separate hydrogeomorphic units with maximum dimension is 5 km X 2 km. Nijkasba dune along the coast in the southern part of Khejuri II Block is the largest. The Khejuri dune, itself hosts the Khejuri village is about 2 sq km. Total area under dune sands is 6.6364 sq km. The dunes are highly potential, yield 0.66 to 6 m^3/hr, drawdown within 2 m. The pre-monsoon static water level varies from 2.5-7.4 mbgl. In post monsoon time it rests within 1-3.25 mbgl. The larger the dune area better is potentiality and sustainability against pumping.

The total rainfall resource available has been assessed by Rainfall Infiltration Factor method with RIF as 25% and considering normal monsoon rainfall 1.3643 m. The natural discharge is taken as 10%. Recharge due to non monsoon rainfall is negligible.

Therefore, the total available annual resource from dune sands is estimated as **2.04 MCM.**

11.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from Tertiary aquifers the following chemical parameters are detected in Khejuri II block.

Table 11.9 Results of Chemical analysis of Tertiary aquifer in Khejuri II

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO_3	HCO_3	TA as CaCO3	Cl	SO_4	NO_3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO_4	Fe
1	Padurveri	Khejuri II	Dune	7.89	2709	bdl	325	397	483	5.3	13	58	30	270	38	23	2.8	bdl
2	Khejuri Zero Point	Khejuri II	Dune	7.84	469.8	300.7	0	195.2	160	120.5	BDL	0.32	32	24.3	180	41.3	5.8	0.86
3	Khejuri Village	Khejuri II	Dune	7.50	1641	1050.2	0	225.7	185	347.4	BDL	0.49	52	38.8	290	184.3	53.8	0.79
4	Sherkhanchak	Khejuri II	Tertiary	7.85	1265	bdl	104	353.8	224	2.2	2.5	52	11	175	191	31	3.6	bdl
5	Ramchak	Khejuri II	Tertiary	8.5	1269	bdl	140	329.4	238	8.1	7.6	48	12	170	133	27	4.7	1.64
6	Kastala(Dasp)	Khejuri II	Tertiary	7.8	1350	bdl	425	519	149	19	2.3	130	12	375	155	12	5.2	bdl
7	Kastala ramkrishna ashram	Khejuri II	Tertiary	7.96	1370	bdl	365	445	100	72	42	98	7	275	48	23	1.8	1.05
8	Khejuri	Khejuri II	Tertiary	8.04	1044	bdl	410	500	107	44	4	58	6	170	5	20	1.6	bdl
9	Sundarpur(south baga)	Khejuri II	Tertiary	8.01	1017	bdl	655	799	121	22	41	72	28	295	80	16	3.5	1.62
10	Kasaria EW	Khejuri II	Tertiary	7.65	944	604.2	0	420.9	345	109.9	BDL	0.5	34	35.2	230	115.1	5.6	

The water from Tertiary is fresh. The Dune aquifer from Khejuri village is fresh. The concentration of Fe in ground water is slightly higher than the permissible limit. The water is mostly sodium chloride or bi-carbonate water. The concentration of nitrate and phosphate has reported high at few locations.

11.8 Ground Water Resource Enhancement and Management Plan:

11.8.1 Ground Water Management Plan for drinking purposes

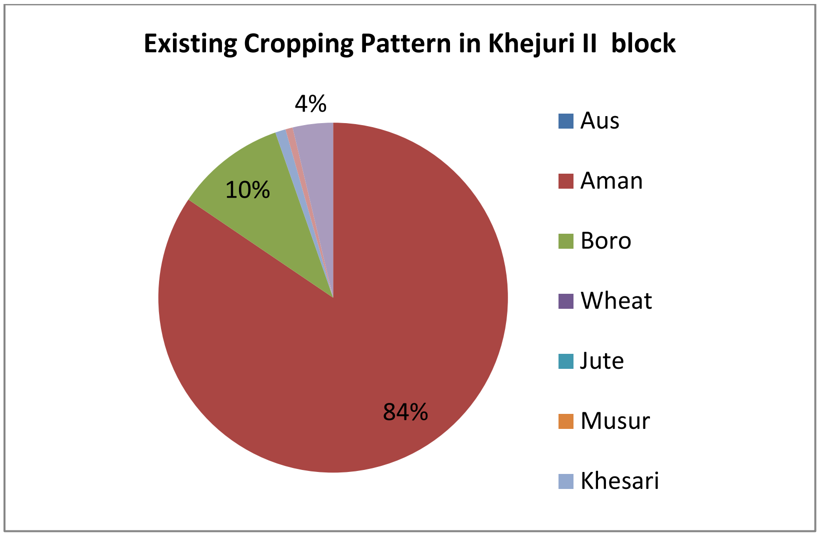
PHED, Govt. of West Bengal is entrusted for supply of drinking water in the block. Besides spot sources of hand pumps, mark II tube wells, PHED has so far commissioned 4 no ground water based water supply schemes. It has been assessed that total covered population through these schemes is about 103682. Therefore, 35781 remaining population need to be brought under water supply schemes for which about 0.5224 MCM water is required. As per the quality of the drinking water standard and prevailing practices of water supply in the block the 40% of the demand is met from Quaternary and 60% from Tertiary aquifer. Considering the average discharge of the individual aquifers, 1 tube well each in Quaternary and Tertiary is proposed. Therefore, further development of this aquifer will definitely affects the ground water regime in the area. It is observed that the probable decline of piezometric surface is 2.24 m and 3.35 m in Quaternary and Tertiary aquifers respectively. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation should always be compensated by construction of suitably design artificial recharge structures in respective aquifers.

Table 11.10 Development Proposal of Tertiary Aquifers with implication on Piezometric Surfaces of Each Aquifer

Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncovered population @40lpcd in MCM	Annual resource proposed to be utilized from Quaternary Aquifer in MCM	Annual resource proposed to be utilized from Tertiary Aquifer in MCM	Total annual unit draft of one TW in MCM (considering average discharge of Quaternary and 8 hrs/day running)	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary and 8 hrs/day running)	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquifer	Decline of piezometric surface in Quaternary Aquifer (in m)	Decline of piezometric surface in Tertiary aquifer(in m)
Khejuri II	137.46	0.5224	0.2090	0.3134	0.1460	0.2920	1	1	2.24	3.35

11.8.2 Management Plan for irrigation:

Present cropping pattern in the block: The major crop in the block is Aman paddy which accounts for 84% of total crops in the block, other includes boro paddy (10%), potato, khesari and mustard.



The cultivable area of the block is 10830 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA in the block is 1793 ha. Further, 9037 ha area is to be brought under irrigation coverage in the blocks. Although, the irrigation tube wells are not very common in the block, however, most of the existing irrigation tube wells are concentrated within the depth range of 100-200 m depth.

Mostly, the Quaternary aquifer in the block is being utilized for limited irrigation uses through construction of shallow and deep tube wells. The aquifers are under semi confined to confined condition. The Quaternary aquifer at the shallow depth is reported brackish to saline in nature. The Tertiary aquifer witnesses long term lowering of water level. Therefore, further development of irrigation tube wells is not recommended. In contrary to these the trivial modification of cropping pattern may brought more area under irrigation in the blocks, therefore increases the intensity of cropping. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 122.40 ha m of water. This volume of water is used to cultivate oilseeds (sunflower/ mustard), potato, pulses etc. as per the prevailing cropping pattern in the block. **Thus, 203.70 ha effective increase in irrigation area** may be created by change in cropping pattern. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability. In Khejuri II block, the well drained dune soil is suitable for cultivation of pan baroj due to its poor susceptibility to stagnant water. Cashew crops, betel leaves may be cultivated from fresh water resource in dune sands to create additional irrigation potential in Khejuri II block, this will in turn create few more irrigation potential.

Table 11.11 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation				Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction(ha)	Volume of Irrgation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor:30 cm)	Potato(Delta factor:60 cm)	Total additional area created in ha	Effective Increase in area(ha)
Khejuri-II	1020	1.2	918	122.40		101.90	135.86	67.93	305.69	203.69

11.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non-committed surface runoff produced in the block is 21.0979 MCM. The non-committed flow is proposed to be utilized to recharge the depleted Quaternary and Tertiary aquifers in the block. As per the available storage space 0.7807 MCM and 0.5967 MCM water is required to fill the available storage space in Tertiary and quaternary aquifers in the block respectively. Therefore, 59 and 45 injection wells with roof top rainwater harvesting structures is recommended in the rural area of the blocks in the respective Tertiary and Quaternary aquifer. The successful implementation of recharge structures may raise the piezometric surface about 6.35-8.35 m. Further, in case of construction of more tube wells in Tertiary and Quaternary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated.

The balance non committed runoff (after utilizing to fill up the depleted aquifers in the block) is estimated as 19.7204 MCM which is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 394 storage / irrigation tanks have been proposed. These tanks can generate additional irrigation potential of 2958.06 ha considering average delta factor of 50 cm for rabi crops, vegetable, etc. Therefore, by change in cropping pattern and utilizing the non-committed runoff for tank irrigation total 3161.76 ha further irrigation potential can be created. Thus, 36% of the uncovered area in the block may be brought under irrigation. The roof top rain water harvesting structures with suitably design injection wells may be proposed to construct in the town area in primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with 1-2 irrigation tanks for harvesting of surface runoff at suitable locations and for subsequent irrigation uses.

Summary of Management Plan:

- *Drinking water tube wells have been recommended both in Quaternary and Tertiary aquifer to meet the uncovered demand from ground water sources. 1 tube well in each aquifer system has been recommended.*
- *The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of injection wells with roof top harvesting arrangements. Thus 59 injection wells in Tertiary and 45 injection wells in Quaternary have been proposed.*
- *Further construction of irrigation tube wells is restricted. The boro area may be reduced by 10% of existing area, and the surplus water may be used to irrigate pulses, oilseed and floriculture crops. Thus additional 204 ha irrigation potential can be generated. The water from dune sands may be utilized for creation of small command area.*
- *The non committed runoff may be used for irrigation tanks. Considering capacity of one tank as 0.05 MCM, 394 irrigation tanks are proposed, preferably one- two in each habitation in the block. This will generate additional irrigation potential of 2958 ha. Thus, the additional irrigation potential created by change in cropping pattern and by*

harvesting surface runoff will bring 36% of the remaining cultivable area in the block under irrigation coverage.

Table 11.12 Proposed Conservation and Recharge Structures based on the available non committed surface runoff and available storage space

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Vol of water kept for conservation/storage tanks in MCM (3-(4+5))	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks (6/8)	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary (4/9)	No of RTRWH with injection well required for Quaternary (5/9)
Khejuri II	137.46	21.0979	0.7807	0.5967	19.7204	0.05	394	0.0133072	59	45

12.0 MANAGEMENT PLAN OF KOLAGHAT BLOCK

12.1 Location, Demography and Rainfall

Kolaghat is located at 22.43°N latitude and 87.87°E longitude Bounded in the east by the River Rupnarayan, in the north Paschim Medinipur district, in the west and south by Panskura and Sahid Matangini Block of Purba Medinipur district respectively.

- Subdivision: Tamluk
- Sub basin: Rupnarayan
- Geographical Area: 145.79 sq km.
- Rural area: 131.73 sq. km
- Urban area: 14.05 sq. km
- Population (2011 Census)

Table 12.1 Total population of the Block

Total Population	Rural Population	Urban Population
2,90,124	2,39,646	50,478

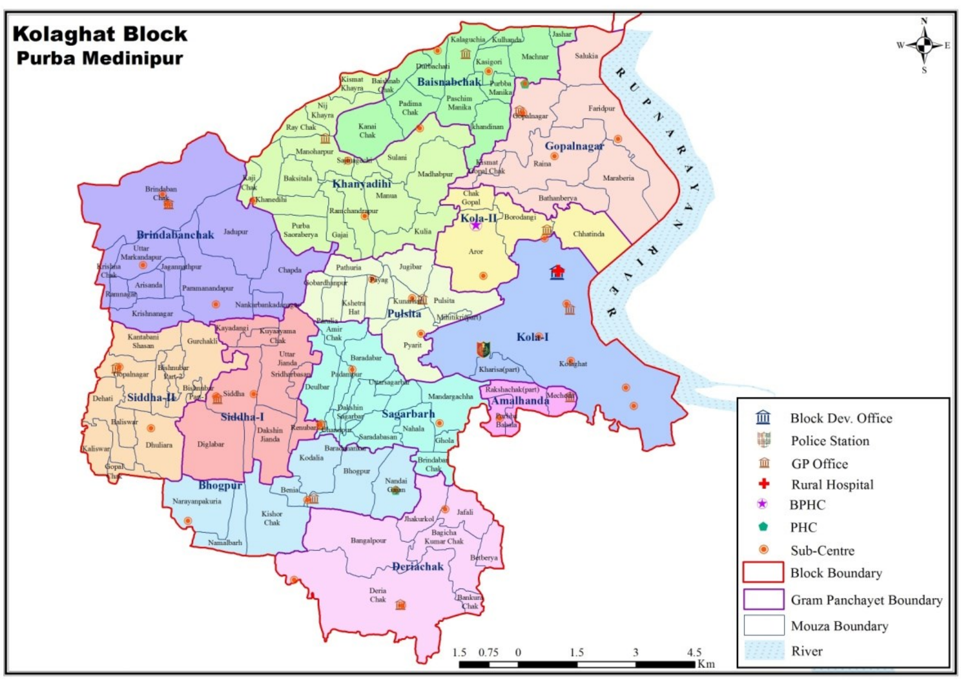


Figure 12.1 Gram-Panchayet and Mouza Map of Kolaghat Block

The block comprises 13 Gram Panchayets, 109 villages, 234 habitations and 59130 households.

Table 12.2 Basic Demographic Detail of Kolaghat Block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	HouseHolds	Population
1	Amalhanda	5	20	4799	22986
2	Baishnabchak	12	20	4964	23747
3	Bhogpur	6	17	6027	28735
4	Brindabanchak	10	19	5838	26259
5	Deriachak	7	19	5267	24210
6	Gopalnagar	6	17	5640	27145
7	Khanyadihi	14	34	5524	26123
8	Kola-i	3	9	1234	6211
9	Kola-ii	7	12	4145	19866
10	Pulsita	9	19	4946	23736
11	Sagarbarh	13	19	4236	19798
12	Siddha-i	8	14	3889	17864
13	Siddha-ii	9	15	2621	12107

Source : PHED, Govt of WB, Website

- **Normal Annual Rainfall** in the district: 1663.40 mm

Table 12.3 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall
Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

12.2 Physiographic and Drainage:

The block is a part of lower Gangetic plain and almost entire blocks is in Rupnarayan sub-basin. The river Rupnarayan which is flowing in SE direction along the eastern boundary of the block controls the drainage network of the block. The tributaries of Rupnarayan also constitute the drainage volume of the block. Average elevation varies from 2-5 m amsl and highest being 9 m amsl. The Rupnarayan, being the main tributary of Hooghly receives, to some extent, tidal flow from Bay of Bengal. The dominant soil type of the block is very poorly drained impermeable clayey soil, however along the course of the river moderately to well drained soils are found.

The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

12.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 12.4 Details of Land use pattern of block (area in ha)

Name of the Block	Forest land	Area under non agriculture uses	Barren land	Permanent pastures and grazing lands	Land under Misc Uses	Culturable wastes	Fallow land other than current	Current fallow	Net area sown
Kolaghat	0	4106			93	6		74	10767

12.4 Agriculture and Irrigation:

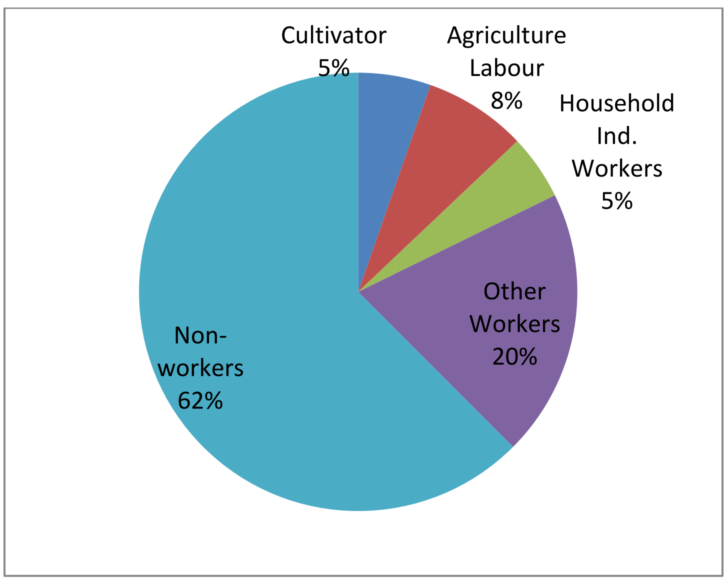


Table 12.5 Distribution of persons engaged in agriculture and other workers/non workers in the Block

In Kolaghat block ,62% of total population is non workers. It is evident from the above diagram that only 13% of the total population in the block is engaged in agriculture either as cultivator or as agriculture labour. %% comprises household industrial workers and 20% of total population comprises other worker. Therefore, the persons available in agriculture sectors in the appears less. Irrigation in the block is achieved by surface and ground water sources. The

Culturable Command area (CCA) created by ground water resources constitute 49% of the total CCA in the block. About 6873.39 ha area has been brought under CCA by surface and ground Water irrigation network**.**

Surface irrigation network comprises canals, tanks, surface flow and lift irrigation. As per the District Statistical Handbook, 2014, about 400 ha area has been covered by canal irrigation. About 1400 ha area has been brought under irrigation by 4050 numbers of irrigation tanks in the block.

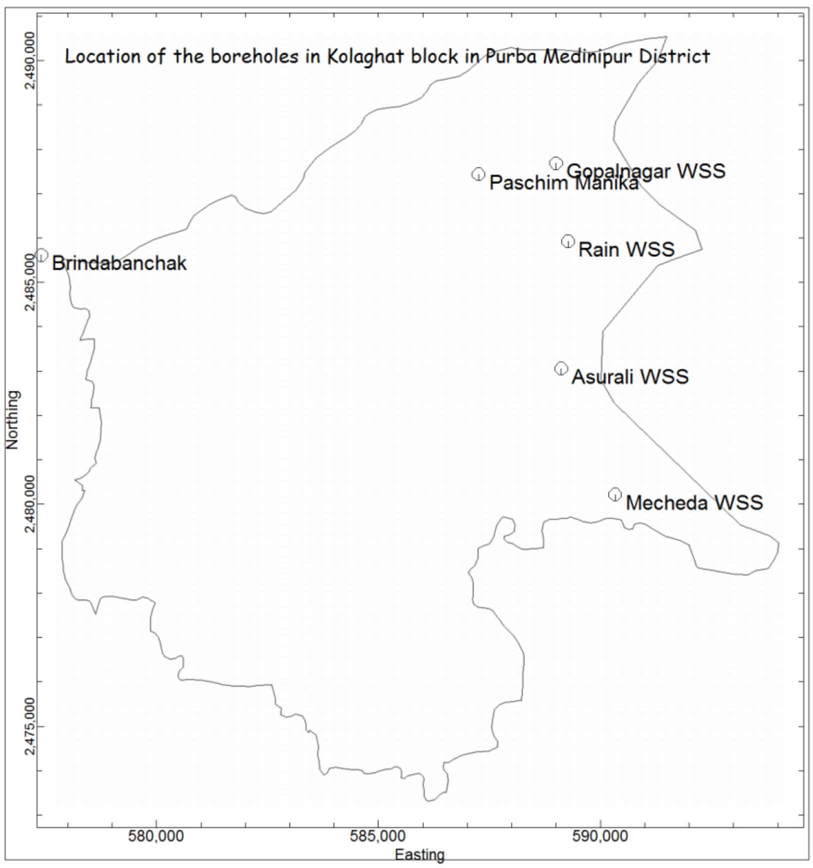
Ground water irrigation is mainly through shallow tube wells and limited numbers of deep tube wells. The CCA created by shallow tube wells is 1570 ha and by DTW 1688.71 ha. The command area of STW and DTW is 10 ha and 40 ha respectively.

Table 12.6 CCA Created by Different Sources in the block (2013-14)

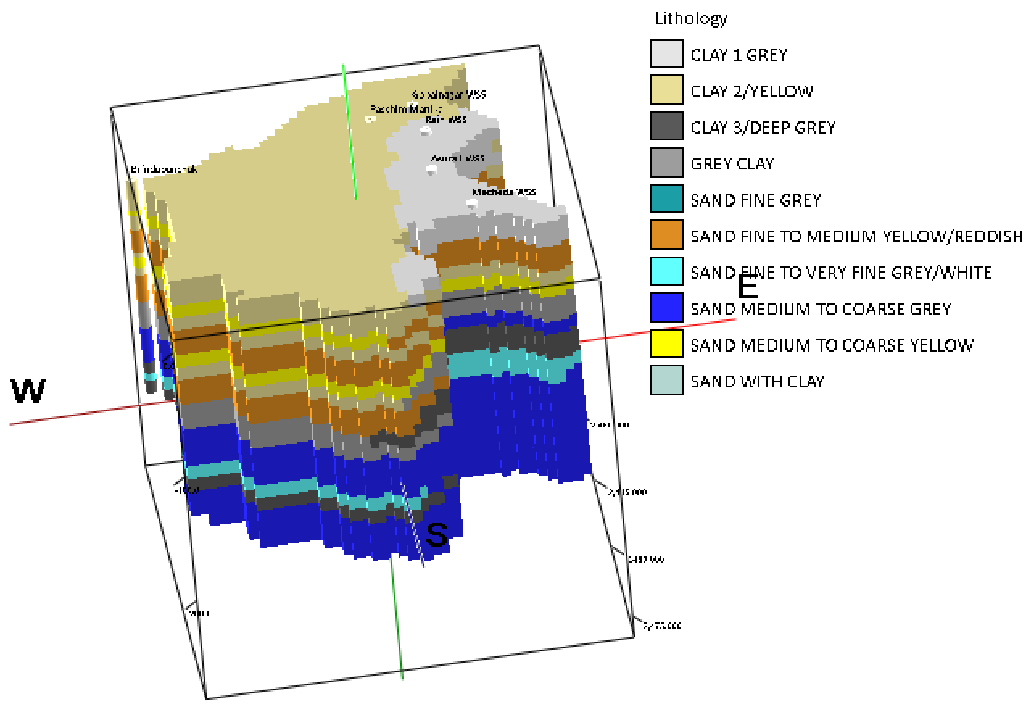
Block Name	Dugwell		Sallow Tubewell		Medium Tubewell		Deep Tubewell		Surface Flow		Sarface Lift		CCA(ha.) Total CCA(ha.)		
	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	Ground Water	Surface Water	
Kolaghat	6.00	97.24	176.00	1570.35	1.00	20.00	44.00	1688.71	52.00	1178.53	163.00	2318.56	3376.30	3497.09	6873.39

12.5 Geology and Sub-Surface Geology

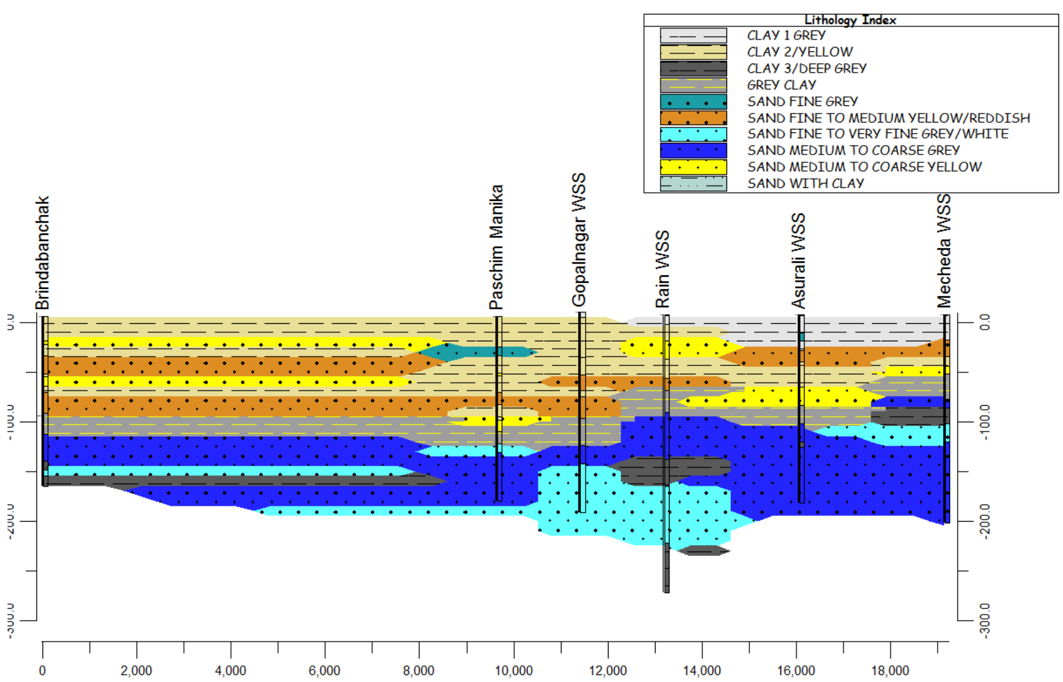
The block is covered by Holocene sediments. The newer alluvium of Holocene age is underlain by Pleistocene Quaternary sediments. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt. Departments, the actual lithology and interpreted aquifer models are prepared, and aquifer systems has been classified.



Lithology Model in Kolkaghat Block in Purba Medinipur district

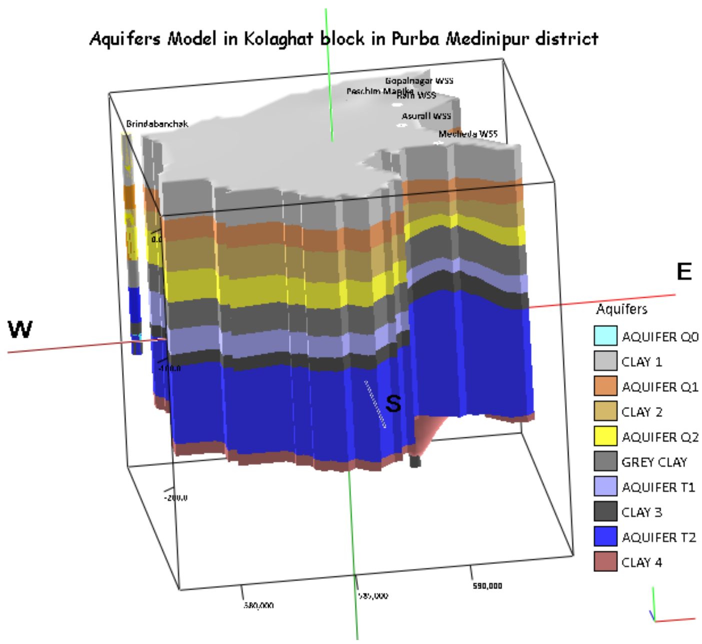


Lithological section along Brindabanchak-Rain-Mecheda in Kolghat Block



The lithology model reveals that the block is underlain by thick yellow and gray clay (20-30m) from the surface. The lithology is represented by alternate sequence of sands of fine to medium and coarse and clay. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and tertiary boundary is marked by occurrences of thick gray clay. Tertiary gray clay is thick and consistent and average thickness of the clay in the block is about 21.33 m.

12.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:



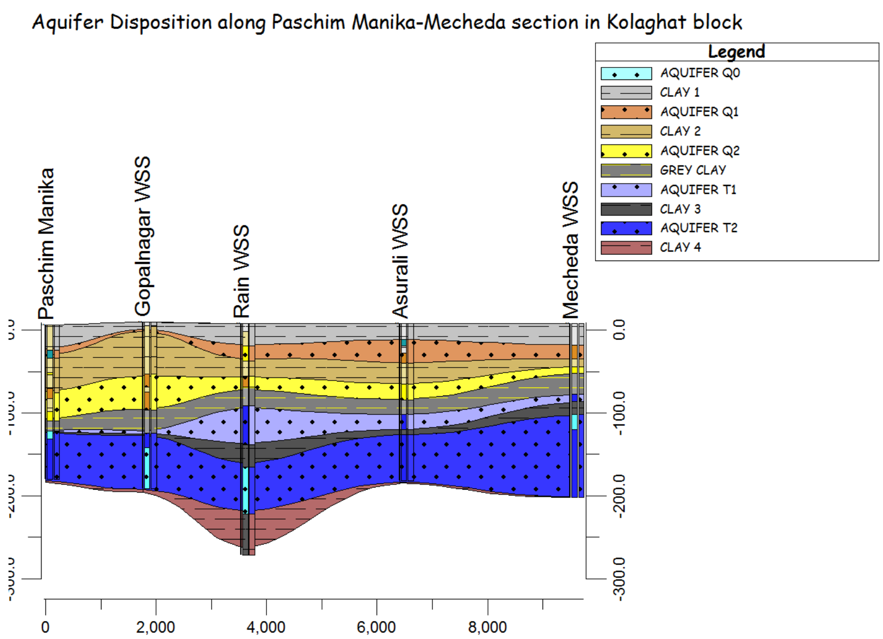


Table 12.7 Disposition of Aquifers and Q/T Boundary In Kolaghat Block

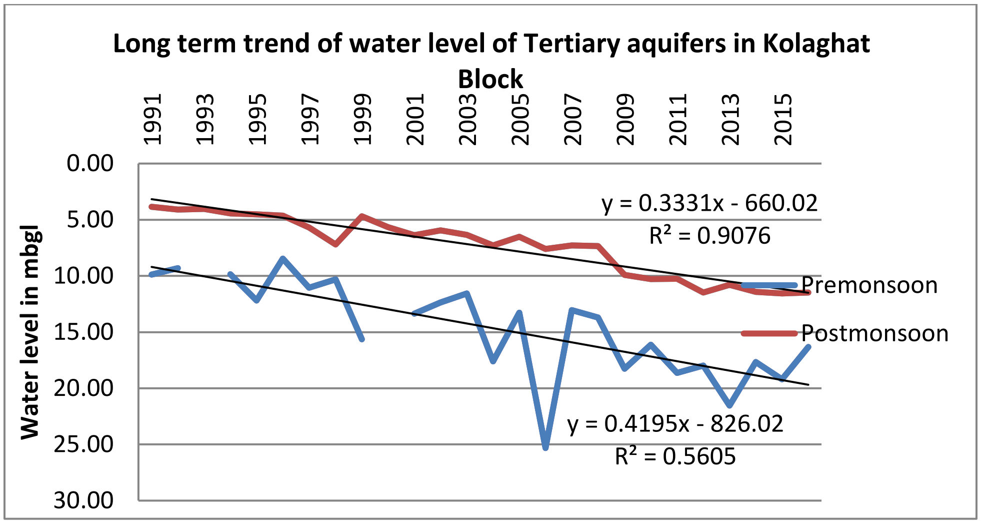
Aquifer Q1			Aquifer Q2			Aquifer T1			Aquifer T2			Q/T Boundary		
From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
28.20	46.31	18.10	67.65	91.00	23.35	103.09	128.62	25.54	135.80	203.40	67.60	91.00	112.33	21.33

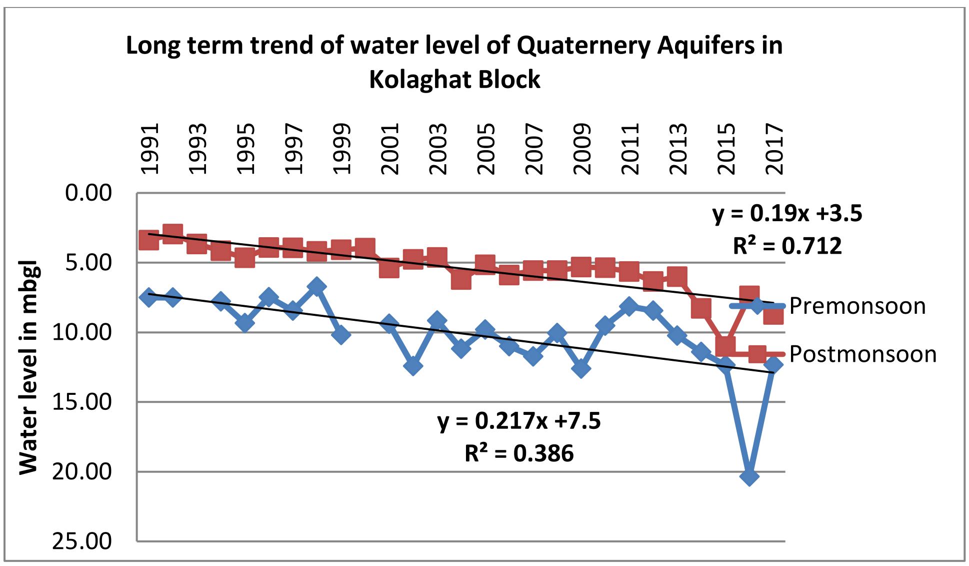
The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. The cumulative thickness of Tertiary aquifer in the area is more (93.14 m) than that of quaternary aquifers (41.45 m).

Ground water Regime

Ground water in both the aquifer system is under confined condition. Pre and post monsoon water level have been monitored from number of observation wells of each aquifer systems. The data of CGWB and SWID has been compiled and long-term water level 1991-2017 has been analyses from SWID data. It is observed that both aquifer system registers a long term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow towards SW direction from 10 m below sea level to 14 m below sea level in Tertiary and 4 m to 14 m below sea level in Quaternary aquifers.

Aquifer system	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m below msl)
Quaternary	5	10.17-14.5	6.36-11.09	21 cm fall	19 cm fall	-4 to -14
Tertiary	13	15.5-20.65	10.06-15.00	40 cm fall	34 cm fall	-8.7 to -14.15





Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is about 90-180 m^3/hr and specific capacity 25-35 m^3/hr/m drawdown. Irrigation shallow tube wellsin the quaternary aquifer is reported to yield at 30-50 m^3/hr.

***Aquifer* Wise Ground Water Resource Availability**

The entire block is under confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl , therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area.

Table 12.8 Details of aquifer wise resource availability (in MCM) in Block

Resource Availability	Quaternary Aquifer	Tertiary Aquifer
Resource by Storage	2.9065	4.4220

Table 12.9 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in ($m^{2/}$day)	Annual Flow in MCM
Kolaghat	16.67	0.000388	2000.00	4.72

12.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from shallow Phreatic aquifer, Quaternary and Tertiary aquifers the following chemical parameters are detected in Kolaghat block.

Table 12.10 Aquifer wise chemical parameter of the block

Sl.No	Village	Aquifers	pH	EC µS/cm at 25°C	CO_3	HCO_3	TA as $CaCO_3$	Cl	SO_4	NO_3	F^-	Ca as Ca	Mg as Mg	TH as $CaCO_3$	Na	K	PO_4	SiO_2	Fe
1	Kolaghat	Tertiary	8.1	816	bdl	403	330	53	2	1	0.11	42	1	120	133	15.6	2.5	5	0.64
2	Bathanberia	Tertiary	7.85	916	bdl	372	305	78	29	15	0.35	44	15	55	184	3.9	3.8	14	0.4
3	Mecheda	Tertiary	7.56	880	bdl	305	372	71	2.3	1.2	0.02	48	16	185	133	12	1.7	9.8	1.01
4	Diglabag	Aquifer 0 (phreatic)	7.73	638	bdl	150	183	192	3.6	1.5	0	78	9	230	46	12	3.8	6.3	bdl
5	Gurchakli(sitala mandir	Tertiary	7.93	1843	bdl	40	49	46	58	42	0.31	26	12	115	345	43	0	2.8	bdl
6	Siddha	Quaternary	7.81	1321	bdl	760	927	188	34	2.3	0.03	78	17.01	265	138	66.3	1.5	11	8.4
7	Khandinan(no 8)	Tertiary	7.88	1430	bdl	355	433	206	410	42	0.98	130	34.02	205	230	39	3.4	8.3	bdl

The water from each systems are potable except in few cases is little brackish in nature.

12.8 Ground Water Resource Enhancement and Management Plan:

12.8.1 Ground Water Management Plan for drinking purposes

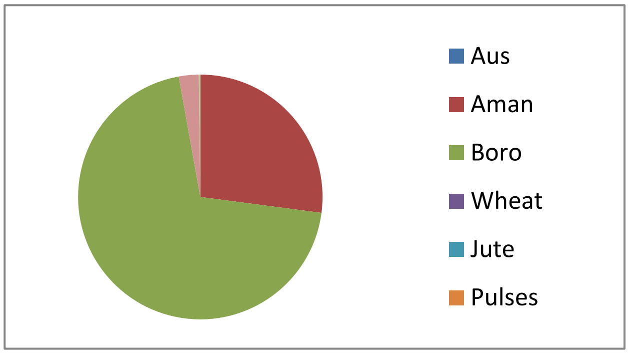
PHED, Govt. of West Bengal is entrusted for supply of drinking water in the block. Besides spot sources of hand pumps, mark II tube wells PHED has so far commissioned 5 no ground water-based water supply scheme in the block. It has been assessed that total covered population through these schemes is about 75203. Therefore, 215021 remaining population need to be brought under water supply schemes for which about 3.1393066 MCM water is required. Both quaternary and Tertiary aquifers may be developed for supply of drinking water to the uncovered population and following the prevailing practices in the area 60% of the proposed demands may be met from Tertiary and rest 40% from Quaternary. Thus, 9 drinking water tube wells in Quaternary and 6 drinking water tube wells in Tertiary may further be constructed in phases to meet the demand from ground water resources.

Table 12.11 Development Proposal of Quaternary and Tertiary Aquifers with implication on Piezometric Surafces of Each Aquifers

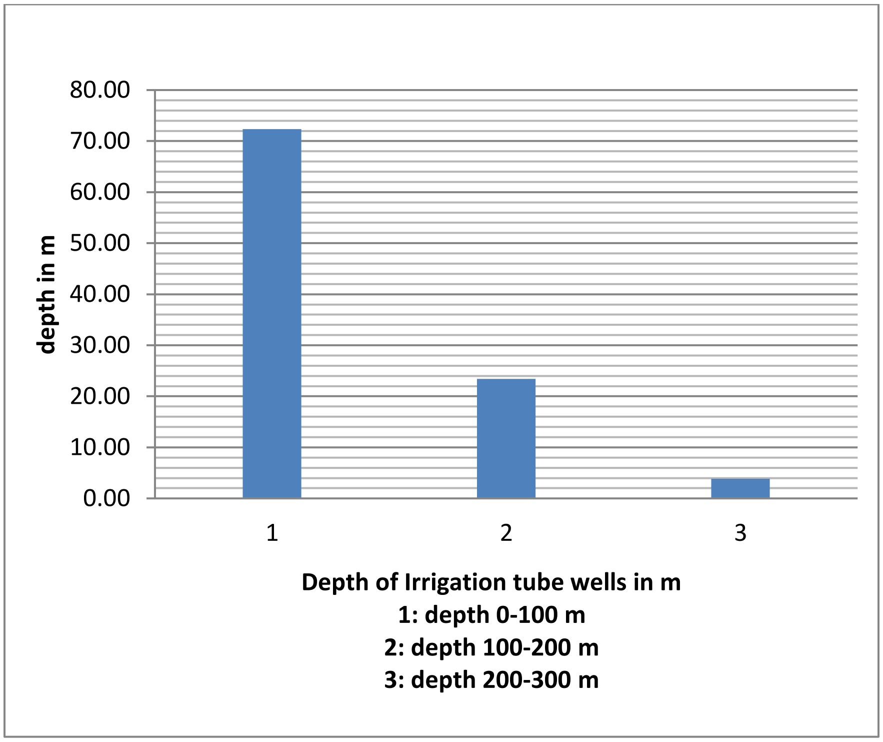
Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncovered population @40lpcd in MCM	Annual resource proposed to be utilized from Quaternary Aquifer in MCM	Annual resource proposed to be utilized from Tertiary Aquifer in MCM	Total annual unit draft of one TW in MCM (considering average discharge of Quaternary and 8 hrs/day running)	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary and 8 hrs/day running)	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquifer	Decline of piezometric surface in Quaternary Aquifer (in m)	Decline of piezometric surface in Tertiary aquifer(in m)
Kolaghat	145.79	3.1393066	1.25572264	1.883584	0.1314	0.292	9	6	24.19	36.29

It is to be noted that, surface water-based water supply schemes from River Rupnarayan are proposed to be completed by 2019 by PHED, Govt. of West Bengal, to cover the entire population in Kolaghat block. The water supply to the population from ground water resources may be kept for alternative provisions or in case of urgencies.

12.8.2 Management Plan for irrigation:



Present cropping pattern in the block: The major crop in the block is boro paddy which accounts for more than 70% of total crops in the block, other includes rain fed aman paddy , little oilseeds and potato.The cultivable area of the block is 10940 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA in the block is 6873.39 ha. The ground water irrigation is accomplished by 176 shallow and medium deep tube wells and 40 deep tube wells. Further, 4066.61 ha area is to be brought under irrigation coverage in the blocks.



More than 70% of irrigation tube wells lie within the depth range of 0-100 m and 22% lies within 100-200 m.

Since, both Quaternary and Tertiary aquifers in the block is under semi confined to confined condition and witnesses steady decline of water level therefore, further development for irrigation is not recommended. In contrary to these the trivial modification of cropping pattern may bring more area under irrigation in the blocks, therefore increases the intensity of cropping. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 990 ha m of water. This volume of water is used to cultivate oilseeds (sunflower/ mustard), pulses and floriculture crops like merrigold, bell, tube rose etc. Thus, 2563 ha effective increase in irrigation area may be created by change in cropping pattern. Owing to the nature of soil types, wheat and potato are not recommended. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability.

Table 12.12 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage with maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation				Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction(ha)	Volume of Irrgation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor: 30 cm)	Floriculture (Bell, Merrigold, tuberose) (Delta factor:22.5 cm)	Total additional area created in ha	Effective Increase in area(ha)
Kolaghat	8249	1.2	7424	990.00		824.18	1098.90	1465.20	3388.28	2563.38

12.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non-committed surface runoff produced in the block is 22.38 MCM. The non-committed flow is proposed to be utilized to recharge both Quaternary and Tertiary aquifers in the block . As per the available storage space 0.2281 MCM and 0.4517 MCM water is required to fill the available storage space in quaternary and tertiary aquifers in the block. Therefore, 34 and 17 injections well with roof top rain water harvesting structures is recommended in the blocks in tertiary and quaternary aquifers respectively. The successful implementation of recharge structures may raise the piezometric surface 10-12m. Further, in case of construction of more tube wells in Tertiary and Quaternary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated.

The remaining non committed runoff, 21.6966 MCM is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 434 storage / irrigation tanks have been proposed. These tanks can generate additional irrigation potential of 3254 ha considering average delta factor of 50 cm for rabi crops, vegetable, horticulture/ floriculture crops. Therefore, by change in cropping pattern and utilizing the non-committed runoff for tank irrigation total 5818 ha further irrigation potential can be created. Thus, the entire cultivable area in the block may be brought under irrigation. There are 4 census towns in the block, the roof top rainwater harvesting structures with suitably design injection wells may be proposed to construct in the census towns in the primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with an irrigation tank for harvesting of surface runoff at suitable locations and for subsequent irrigation uses.

Summary of Management Plan:

- *Drinking water tube wells have been recommended in Tertiary and Quaternary aquifers to meet the uncovered demand from ground water sources. 9 tube wells in Quaternary and 6 tube wells in Tertiary have been proposed.*
- *The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of 34 injection wells in Tertiary and 17 injection wells in Quaternary with roof top harvesting arrangements.*
- *Further construction of irrigation tube wells in either aquifer may be restricted. The boro area may be reduced by 10% of existing area, and the surplus water may be used to irrigate pulses, oilseed and floriculture crops. Thus additional 2563 ha irrigation potential can be generated.*
- *The non committed runoff, may be used for irrigation tanks. Considering capacity of one tank as 0.05 MCM, 434 irrigation tanks are proposed, preferably one in each habitation in the block. This will generate additional irrigation potential of 3254 ha. Thus total 5818 ha additional irrigation potential can be created and, the entire cultivable area in the block may be brought under irrigation.*

Table 12.13 Proposed Conservation and Recharge Structures based on the available non comitted surface runoff and available storage space

ame of the block	Geographical area (in Sq.Km.)	Non-Comitted surface runoff available (MCM)	Total surface runoff/ water required to fill staorage space in Tertiary (MCM)	Total surface runoff/ water required to fill staorage space in Quaternary (MCM)	Vol of water kept for conservation /sorage tanks in MCM (3-(4+5))	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks (6/8)	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary (4/9)	No of RTRWH with injection well required for Quaternary (5/9)
1	2	3	4	5	6	7	8	9	10	11
Kolaghat	145.79	22.3764	0.4517	0.2281	21.6966	0.05	434	0.0133072	34	17

13.0 MANAGEMENT PLAN OF MAHISADAL BLOCK

13.1 Location, Demography and Rainfall

Mahisadal block is a part of Tamluk subdivision. Mahisadal is located at 22.1833°N latitude and 87.9833 °E longitude Bounded in the east by Runarayan River, in the south and south east by Haldia and Sutahata block, in the south by Nandigram II and Chandipur block and in the west by Nandakumar block of Purba Medinipur district.

- Subdivision: Haldia
- Sub basin: Rupnarayan
- Geographical Area:
- Mahisadal: 146.48 sq km.
- Population (2011 Census)

Table 13.1 Total population of the Block

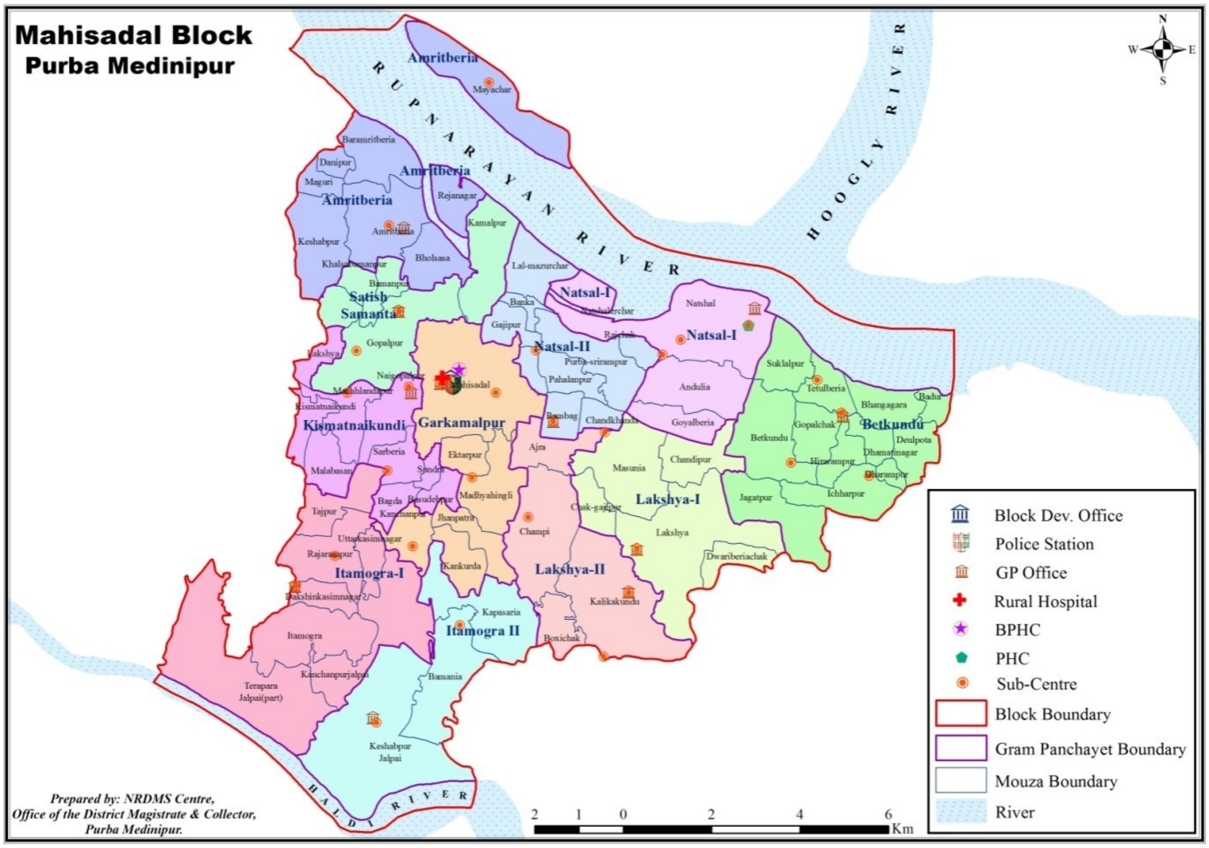
	Rural Population	Urban Population	Total
Block	199613	6664	206277

The block comprises 11 Gram Panchayets, 74 villages, 158 habitations, 1 census town.

Table 13.2 Basic Demographic Detail of Mahisadal Block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	House-Holds	Population
1	Amritberia	7	11	4517	19068
2	Betkundu	12	18	5757	26904
3	Garkamalpur	6	12	4416	21744
4	Itamogra-i	7	18	3753	17468
5	Itamogra-ii	3	15	3424	16290
6	Kishmat Naikundu	11	12	4360	20564
7	Lakshya-i	5	12	3697	16625
8	Lakshya-ii	4	11	3318	14996
9	Natshal-i	3	23	3468	16256
10	Natshal-ii	10	14	4188	19057
11	Satish Samanta	6	12	3912	17910
	Total	74	158	44810	206882

Source: PHED, Govt. of WB, Website



- **Normal Annual Rainfall** in the district: 1663.40 mm

Table 13.3 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall
Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

13.2 Physiographic and Drainage:

The block comprises coastal blocks in Purba Medinipur district and is a part of lower Gangetic plain. It lies in Rupnarayan sub basin. The river Rupnarayan is flowing along the north eastern boundary of the block where Hooghly river joins Rupnarayan while approaching to Bay of Bengal. Haldi river ibn flowing in south east direction along the southern boundary of Mahisadal block. Runarayan, Haldi and its drainage channel have tidal influences. The average elevation is 4-5 m amsl. The dominant soil type of the block is very poorly drained impermeable clayey soil. The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

13.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 13.4 Details of Land use pattern of block (area in ha)

Name of the block	Reporting area	Forest area	Area under non-agriculture wastes	Barren and un-culturable lands	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Net area sown
Mahisadal	14525	0	4450	7		93			50	9925

13.4 Agriculture and Irrigation:

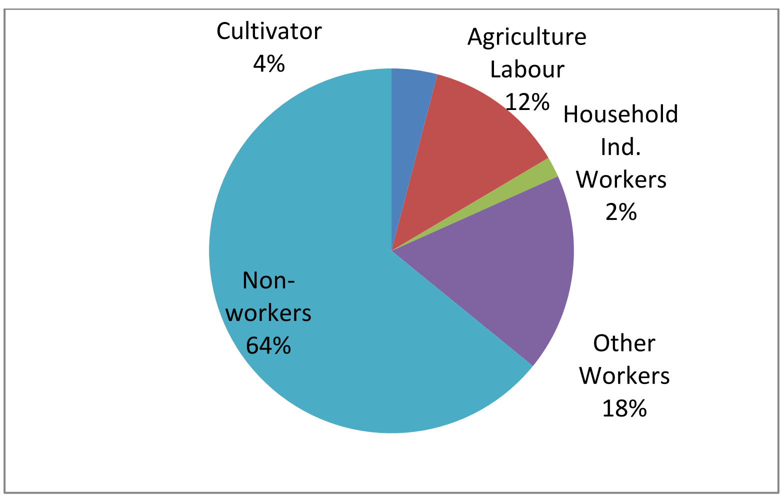


Table 13.5 Distribution of persons engaged in agriculture and other workers/non workers in the Block

In Mahisadal block, 64% of total population is non workers. It is evident from the above diagram that 16% of the total population in the block is engaged in agriculture either as cultivator or as agriculture labour. 2% comprises Household industrial workers and 18% comprises other worker.

Cultivable area in the block is 10068 ha. Irrigation in the block is achieved by surface and ground water sources. The Culturable Command area (CCA) created by surface water and ground water resources in the block is 7052.24 ha. 76% of the irrigation coverage achieved by surface water and the rest 24% by ground water sources. Due to the brackish nature of ground water in shallow aquifer the irrigation development from ground water resources are limited in Mahisadal block. Attempt may be initiated to bring further area under cultivation in the block.

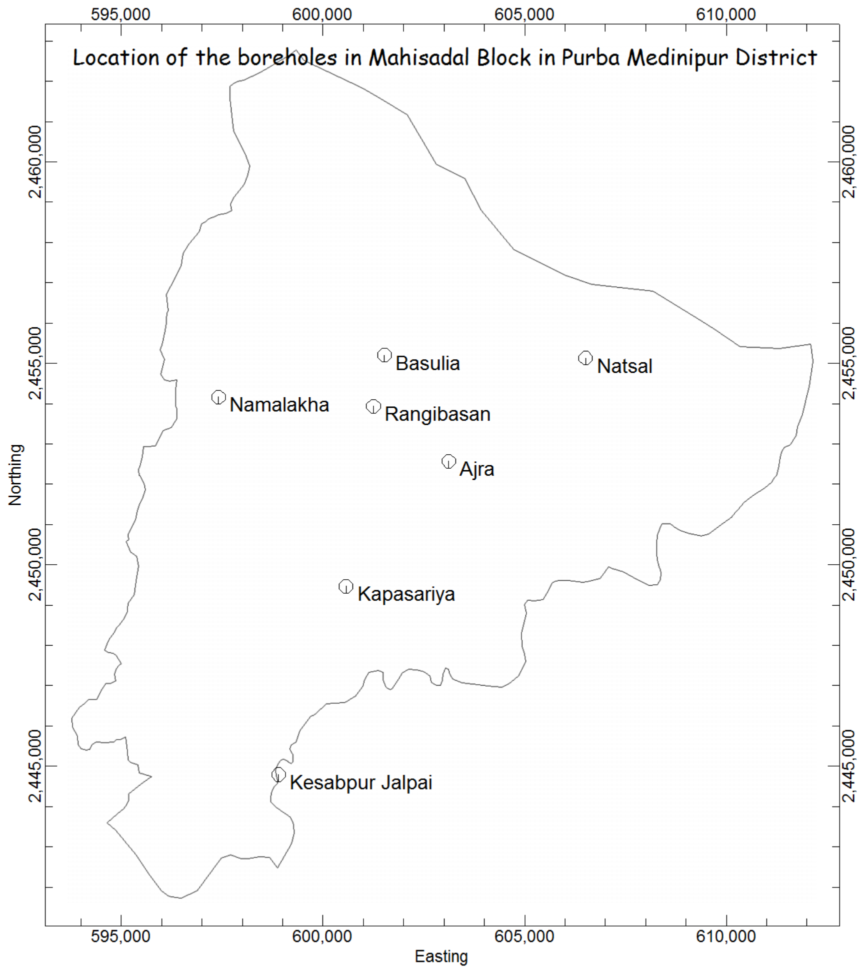
Surface irrigation network comprises irrigation from tanks, surface flow and lift irrigation. As per the District Statistical Handbook, 2014, no irrigation coverage from canal has been reported. **Ground water irrigation** is limited and is accomplished through limited numbers shallow tube wells and deep tube wells. The CCA created by about 76 shallow tube wells is 1429.62 ha, besides that some more area is under irrigation through medium and deep tube wells.

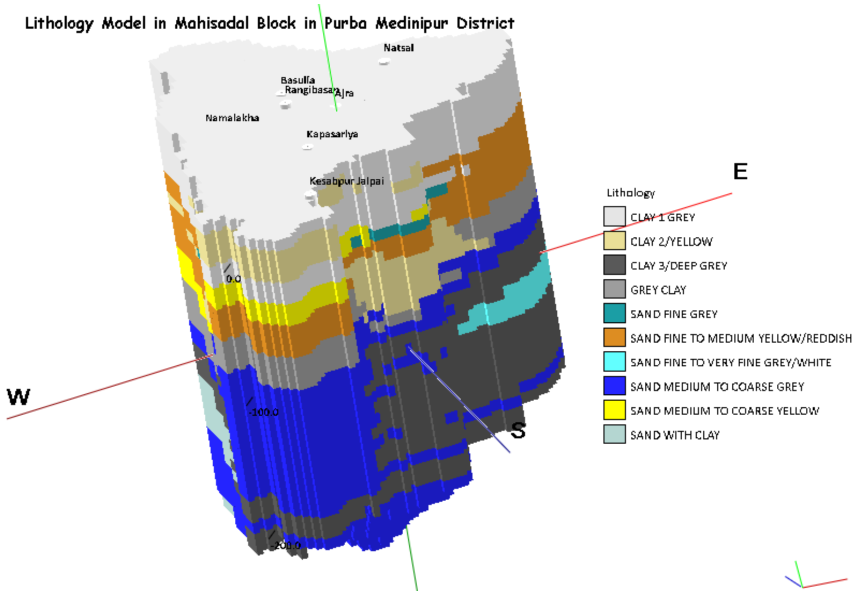
Table 13.6 CCA Created by Different Sources in the block (2013-14

Block Name	Shallow Tubewell		Medium Tubewell		Deep Tubewell		Surface Flow		Surface Lift		CCA(ha.) Total CCA(ha.)		
	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	Ground Water	Surface Water	Total
Mahisadal	76.00	1429.62	1.00	2.00	7.00	243.00	60.00	2369.56	111.00	2983.06	1699.62	5352.62	7052.24

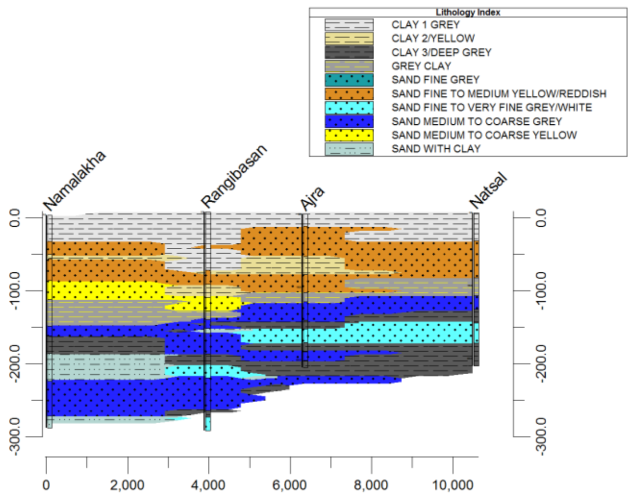
13.5 Geology and Sub-Surface Geology

The block is covered by Holocene sediments. The newer alluvium of Holocene age is underlain by Piestocene Quaternary sediments. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt. Departments, the actual lithology and interpreted aquifer models are prepared and aquifer systems has been classified.

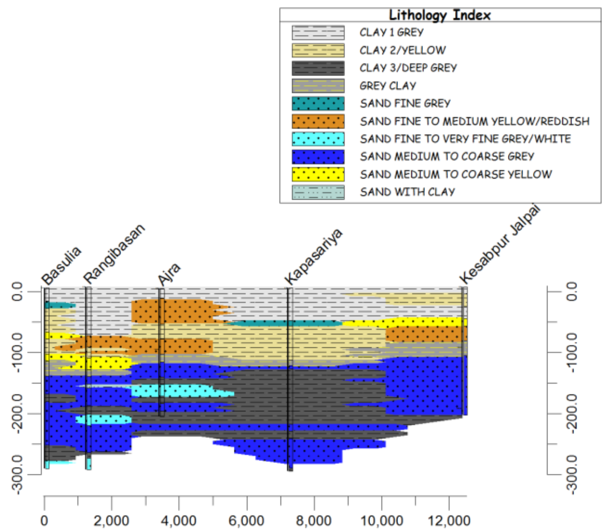

Location of the boreholes in Mahisadal Block in Purba Medinipur District
595,000
600,000
605,000
610,000
2,460,000
2,455,000
2,450,000
2,445,000
Northing
Easting
Basulia
Natsal
Namalakha
Rangibasan
Ajra
Kapasariya
Kesabpur Jalpai


Lithology Model in Mahisadal Block in Purba Medinipur District
Natsal
Basulia
Rangibasan
Ajra
Namalakha
Kapasariya
Kesabpur Jalpai
E
W
S
Lithology
CLAY 1 GREY
CLAY 2/YELLOW
CLAY 3/DEEP GREY
GREY CLAY
SAND FINE GREY
SAND FINE TO MEDIUM YELLOW/REDDISH
SAND FINE TO VERY FINE GREY/WHITE
SAND MEDIUM TO COARSE GREY
SAND MEDIUM TO COARSE YELLOW
SAND WITH CLAY

Lithologic Section along Namlakha-Ragibasan-Natsal Section in Mahisadal Block



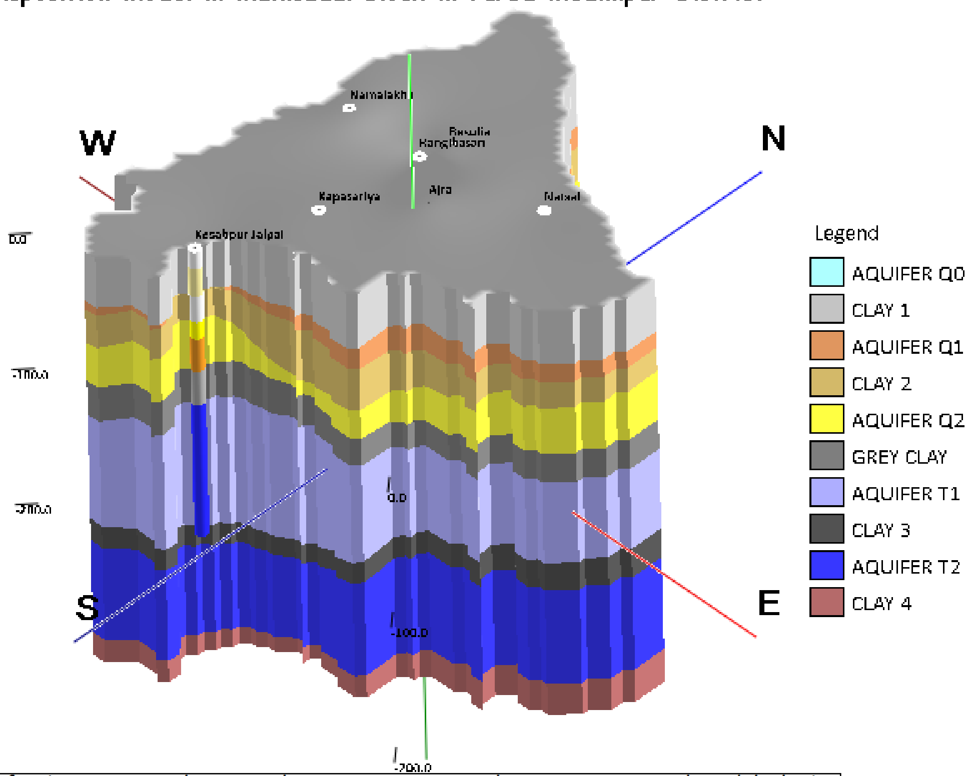
Lithologic Section along Basulia-Kapasariya-K_Jalpai Section in Mahisadal Block



Lithology model reveals that the block is overlain by thick grey surface clay of 40-45 m thick. The lithology is represented by fine to very fine grey sands, medium to coarse yellow to reddish sands, fine to medium gray sands with intervening gray to yellow and dark gray clay. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and Tertiary boundary is marked by occurrences of thick gray clay. The depth of occurrences of Tertiary clay is variable with average depth of 110 mbgl. The depth and thickness of clay varies spatially.

13.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:

Aquifer Disposition Model in Mahisadal Block in Purba Medinipur District



Aquifer Disposition along Namlakha_Natsal Section in Mahisadal Block

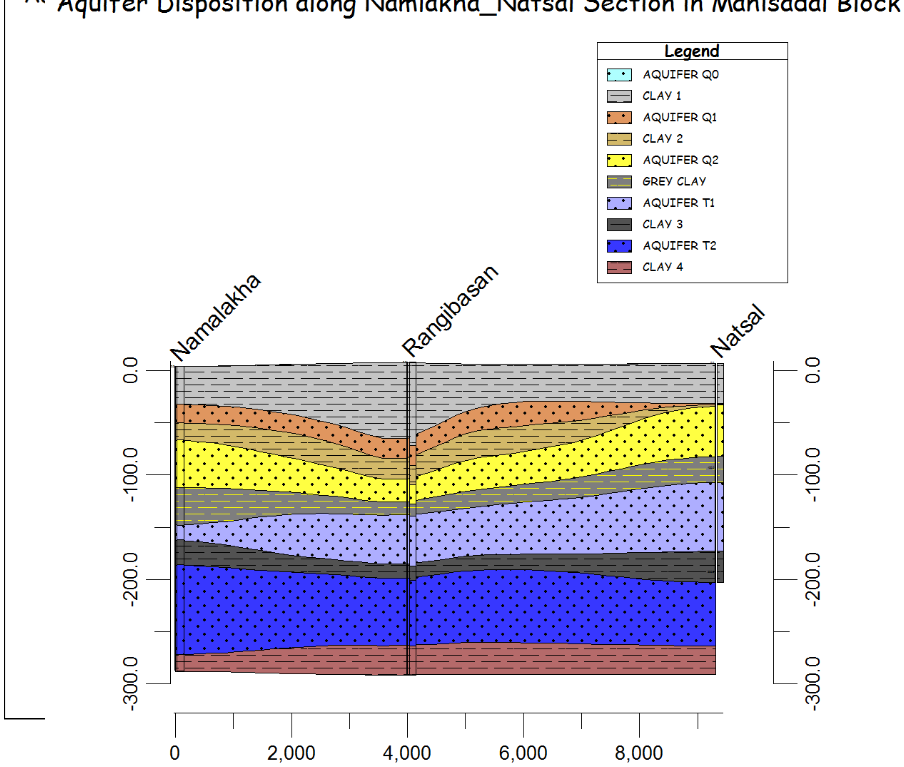


Table 13.7 Disposition of Aquifers and Q/T Boundary in Mahisadal Block

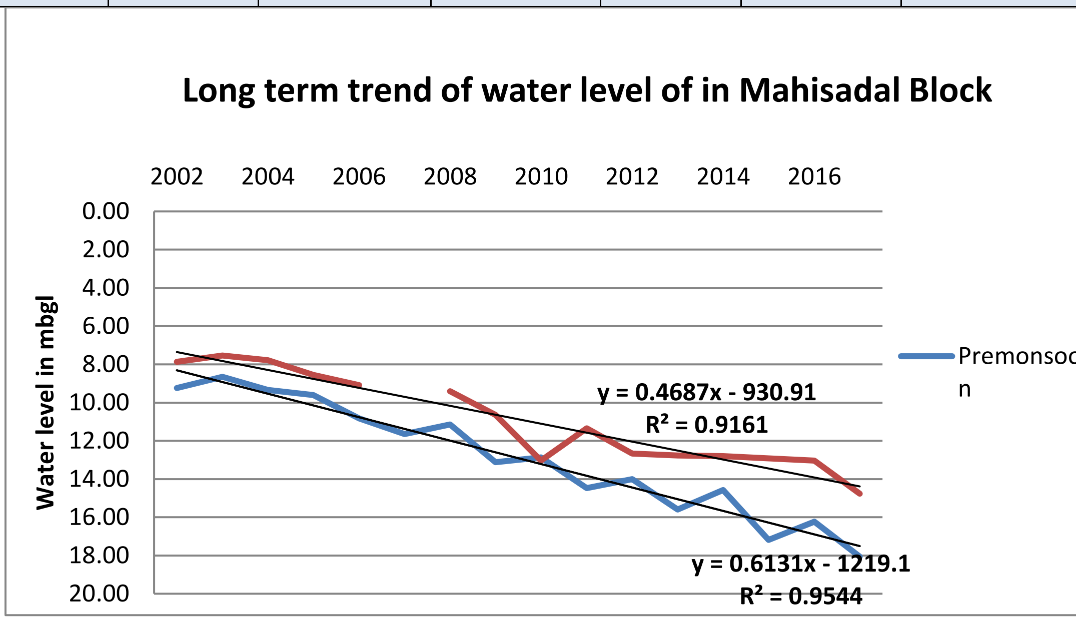
Block	Quaternary Aquifers						Q/T Boundary			Tertiary Aquifers					
	Q1			Q2						T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Mahisadal	44.36	55.94	14.48	78.57	110.43	37.17	110.43	130.86	20.43	130.86	190.86	60.00	203.80	262.20	58.40

The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. Both in E-W and N-S sections across the block all the aquifer components are represented. The thick surface clay is very consistent throughout the block. In the EW section the disposition of both Quaternary and Tertiary aquifers are very consistent where as in NS section the Quaternary aquifers are pinched out at places. The overall thickness of Quaternary aquifers is less than that of Tertiary. The Q/T boundary clay is thick (20 m) consistent throughout the block. The two Tertiary aquifers T1 and T2 are separated by thick uniform steel gray clay.

Ground Water Condition

Groundwater, in both quaternary and tertiary aquifer system is under confined condition. Pre and post monsoon water level have been monitored from number of observation wells in Tertiary aquifer systems. The depth of the wells varies between 168-265 m. Due to the paucity of the working tube wells in the quaternary aquifer, the monitoring data from the quaternary aquifer system was inadequate. The data of CGWB and SWID has been compiled and long term water level 2002-2017 has been analyses from SWID data for Tertiary aquifer only. It is observed that Tertiary registers a long term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow from NW to SE and 6.5 m below sea level to 14.20 m below sea level in Tertiary aquifers. The ground water flow is influenced by local ground water development in the block forming local trough in the block area.

Aquifer system	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m below msl)
Tertiary	12	15.5-18.84	12.45-15.80	61 cm fall	46 cm fall	-6.5 to -14.20 m



Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is about 80-125 m^3/hr with moderate drawdown of 3.36-5.29 m. The specific capacity ranges between 15-25 m^3/hr/m drawdown. The Irrigation tube wells are not very common in Mahisadal block.

***Aquifer* Wise Ground Water Resource Availability**

The entire block is under confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl, therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area.

Table 13.8 Details of resource available in Tertiary aquifer (in MCM) in Block

Resource Availability	Mahisadal block
Resource by Storage	11.2555

Table 13.9 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in ($m^{2/}$day)	Annual Flow in MCM
Mahisadal	18.33	0.000225	2000.00	3.01

13.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from Tertiary aquifers the following chemical parameters are detected in Nandakumar block.

Table 13.10 Results of Chemical analysis of Tertiary aquifer in Nandakumar

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO_3	HCO_3	TA as CaCO3	Cl	SO_4	NO_3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO_4	Fe
1	Mahisadal	Mahisadal	Dug well	8.11	1653	bdl	171	640.5	171	27	35	90	4	240	237	55	2.6	bdl
2	Bethkundu	Mahisadal	Tertiary	7.74	1090	bdl	55	427	128	9	2.3	66	5	185	159	8	7	bdl
3	Rangibasan tw2	Mahisadal	Tertiary	7.19	1868	bdl	73	622.2	299	0	1	94	5	255	260	101	3.2	bdl
4	Kapasaria	Mahisadal	Tertiary	8.15	1363	bdl	73	335.5	220	65	26	62	4	170	209	43	5.4	bdl
5	Champi	Mahisadal	Tertiary	8.32	1149	bdl	183	323.3	167	33	11	50	6	150	173	35	1.9	bdl
6	Jalsai	Mahisadal	Tertiary	8	1124	bdl	260	317	142	28	19	68	2	180	163	20	5	0.39

The water from Tertiary is fresh , EC varies between 1090-1868 **µS/cm**. The water is mostly sodium chloride and sodium bi-carbonate water.

13.8 Ground Water Resource Enhancement and Management Plan:

13.8.1 Ground Water Management Plan for drinking purposes

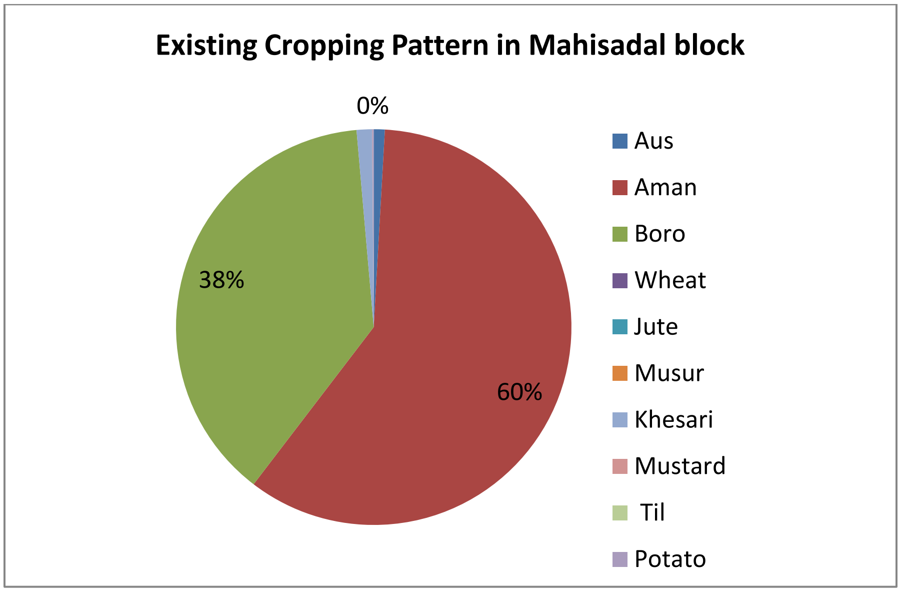
PHED, Govt. of West Bengal is entrusted for supply of drinking water in the block. Besides spot sources of hand pumps, mark II tube wells PHED has so far commissioned 5 no ground water based water supply schemes and 2 more ground water based schemes are under commissioning in the block. It has been assessed that total covered population through the commissioned schemes is about 162149. Therefore, 44128 remaining population need to be brought under water supply schemes for which about 0.6443 MCM water is required. As per the prevailing practices in the block the Tertiary aquifer may be utilized to cater the remaining need of drinking water supply in the block. Thus, 2 drinking water tube wells in Tertiary aquifer may further be constructed in phases to meet the demand from ground water resources. Therefore, further development of this aquifer will definitely affects the ground water regime in the area. It is estimated that the probable decline of piezometric surface in Tertiary aquifer as an impact of installation of additional tube wells would be 6.5 m. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation should always be compensated by construction of suitably design artificial recharge structures in respective aquifers.

Table 13.11 Development Proposal of Tertiary Aquifers with implication on Piezometric Surfaces of Each Aquifer

Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncovered population @40lpcd in MCM	Annual resource proposed to be utilized from Quaternary Aquifer in MCM	Annual resource proposed to be utilized from Tertiary Aquifer in MCM	Total annual unit draft of one TW in MCM (considering average discharge of Quaternary and 8 hrs/day running)	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary and 8 hrs/day running)	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquifer	Decline of piezometric surface in Tertiary aquifer(in m)
Mahisadal	146.48	0.6443	0.0000	0.6443		0.2628	0	2	6.5

13.8.2 Management Plan for irrigation:

Present cropping pattern in the block: The major crops in the block include Aman and Boro paddy. Aman is 60% and Boro includes 38 % of cropped area. The other crops include Aus, Khesari and Potato.



The cultivable area of the block is 10068 ha. The culturable command area (CCA) has been created by mainly by surface irrigation networks and limited area by ground water. Total CCA in the block is 7052.24 ha and therefore, 3015.76 ha area to be brought under irrigation coverage for which diversification in cropping pattern has been proposed.

The Quaternary aquifer in the block is reported to be brackish to saline in nature and in general not developed at all for irrigation uses. Tertiary aquifers in the block is under semi confined to confined condition and witnesses steady decline of water level therefore, further development of irrigation tube wells is not recommended. In contrary to these the trivial modification of cropping pattern may bring more area under irrigation in the blocks. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 763.20 ha m of water. This volume of water is used to cultivate oilseeds (sunflower/ mustard), pulses, potato etc. as per the prevailing cropping pattern in the block. **Thus, 1270.49 ha effective increase in irrigation area** may be created by change in cropping pattern. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability.

Table 13.12 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation				Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction(ha)	Volume of Irrigation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor: 30 cm)	Potato (Delta factor: 60 cm)	Total additional area created in ha	Effective Increase in area(ha)
Mahisadal	6356	1.2	5720	763.20		635.36	847.15	423.58	1906.09	1270.49

13.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non committed surface runoff produced in the block is 22.4823 MCM. The non-committed flow is proposed to be utilized to recharge the depleted Tertiary aquifers in the block. As per the available storage space 1.0248 MCM water is required to fill the available storage space in Tertiary aquifers in block. Therefore, 77 injections well with roof top rain water harvesting structures are recommended in the block. The successful implementation of recharge structures may raise the piezometric surface about 10 m. Further, in case of construction of more tube wells in Tertiary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated.

The remaining non committed runoff, 21.4575 MCM is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 429 storage tanks have been proposed. These tanks can generate additional irrigation potential of 3218 ha considering average delta factor of 50 cm for rabi crops, vegetable, horticulture/ floriculture crops. Few storage tanks may be utilized for other purpose like pisciculture etc. The roof top rain water harvesting structures with suitably design injection wells may be proposed to construct in the census town area in primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with 1-2 irrigation tanks for harvesting of surface runoff at suitable locations and for subsequent irrigation/aquaculture uses.

Summary of Management Plan:

- *Drinking water tube wells have been recommended in Tertiary aquifer to meet the uncovered demand from ground water sources. 2 drinking water tube wells in Tertiary have been proposed.*
- *The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of 77 injection wells in block with roof top harvesting arrangements.*
- *Further construction of irrigation tube wells is restricted. The boro area may be reduced by 10% of existing area , and the surplus water may be used to irrigate pulses, oilseed and potato for more diversification of crops. Thus additional 1270 ha irrigation potential can be generated.*
- *The non committed runoff may be harvested for storage tanks. Considering capacity of one tank as 0.05 MCM, 429 tanks are proposed, preferably one- two in each habitation in the block. This may generate additional irrigation potential of 3218 ha. Therefore, by proposed change in cropping pattern and by irrigation from tanks through harvesting of runoff total additional irrigation potential generated is 4489.11 ha which can bring the total cultivable area in the block under irrigation coverage.*

Table 13.13 Proposed Conservation and Recharge Structures based on the available non committed surface runoff and available storage space

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Vol of water kept for conservation/storage tanks in MCM	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary	No of RTRWH with injection well required for Quaternary
Mahisadal	146.48	22.4823	1.0248		21.4575		429	0.0133072	77	

14.0 MANAGEMENT PLAN OF MOYNA BLOCK

14.1 Location, Demography and Rainfall

Moyna is located at 22.23°N latitude and 87.78 °E longitude Bounded in the east by Tamluk and Nandakumar block , in the north by Panskura block, in the south by Bhagawanpur I block of Purba Medinipur district and in the west by Paschim Medinipur district.

- Subdivision: Panskura
- Sub basin: Keleghai
- Geographical Area: 158.69 sq km
- Population (2011 Census)

Table 14.1 Total population of the Block

	Rural Population	Urban Population	Total
Block	220330	6597	226927

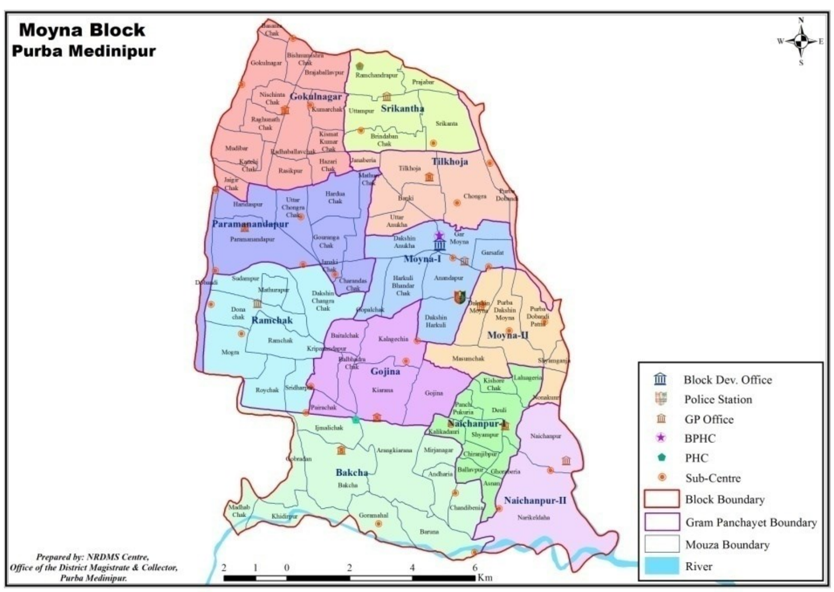


Figure 14.1 Gram-Panchayet and Mouza Map of Moyna Block

The block comprises 11 Gram Panchayets, 89 villages, one census town, 359 habitations and 53356 households.

Table 14.2 Basic Demographic Detail of Moyna Block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	HouseHolds	Population
1	Bakcha	11	36	7639	31972
2	Gojina	7	25	4835	18501
3	Gokulnagar	14	81	6147	25574
4	Moyna-i	7	22	3498	15019
5	Moyna-ii	6	21	4034	17456
6	Naichanpur-i	10	35	3462	14890
7	Naichanpur-ii	5	24	5405	25429
8	Paramanandapur	9	41	5025	21939
9	Ramchak	9	31	5909	25586
10	Srikantha	5	26	4337	19287
11	Tilkhoja	6	17	3899	16922
	Total	**89**	**359**	**54190**	**232575**

Source: PHED, Govt of WB, Website

Normal Annual Rainfall in the district: 1663.40 mm

Table 14.3 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall
Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

14.2 Physiographic and Drainage:

The block is a part of lower Gangetic plain. Moyna is bounded by the rivers Kasai and Chandia from the east and west, respectively. River Chandia and Keleghai are on the south and the Baksi canal is on the north. Moyna area itself constitutes a local basin type configuration. Number of khals are characteristics of the block . Due to the basinal configuration the block often witnesses water logged condition. The average elevation is 6 m amsl. The dominant soil type of the block is very poorly drained impermeable clayey soil. The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

14.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 14.4 Details of Land use pattern of block (area in ha)

Name of the block	Reporting area	Forest area	Area under non-agriculture wastes	Barren and un-culturable lands	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Net area sown
Moyna	14712	0	3649			46		1		11016

14.4 Agriculture and Irrigation:

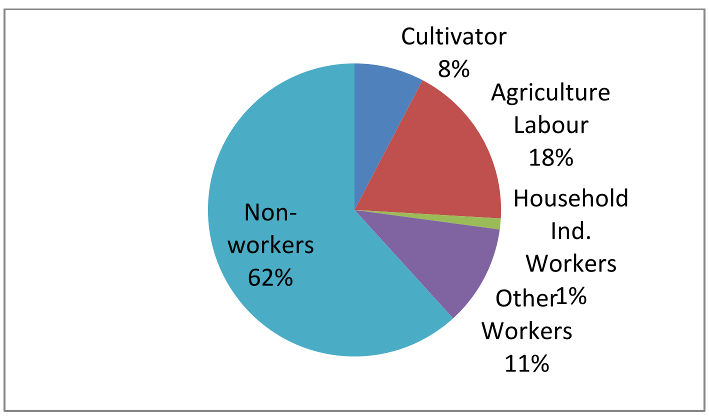


Table 14.5 Distribution of persons engaged in agriculture and other workers/non workers in the Block

In Moyna block, 62% of total population is non workers. It is evident from the above diagram that 26% of the total population and 67 % of the total workers in the block is engaged in agriculture either as cultivator or as agriculture labour. 1% comprises Household industrial workers and 11% comprises other worker.

Irrigation in the block is achieved by surface and ground water sources. The total cultivable area in the block is 11063 ha. The Culturable Command area (CCA) created in the block is 3843 ha. Surface water resources constitute 40% of the total CCA in the block. Ground water irrigation coverage is 60% in the block.

Surface irrigation network comprises tanks, surface flow and lift irrigation. As per the District Statistical Handbook, 2014 canal network is not reported in the block. A considerable area is brought under irrigation by 2855 numbers of tanks. Surface flow, lift irrigation comprises other mode of surface irrigation networks in the block.

Ground water irrigation is accomplished mainly through shallow tube wells and deep tube wells. The CCA created by about 257 shallow tube wells is 1569 ha and by 15 deep tube well 173 ha. Few dug well irrigation has also been reported in Moyna block.

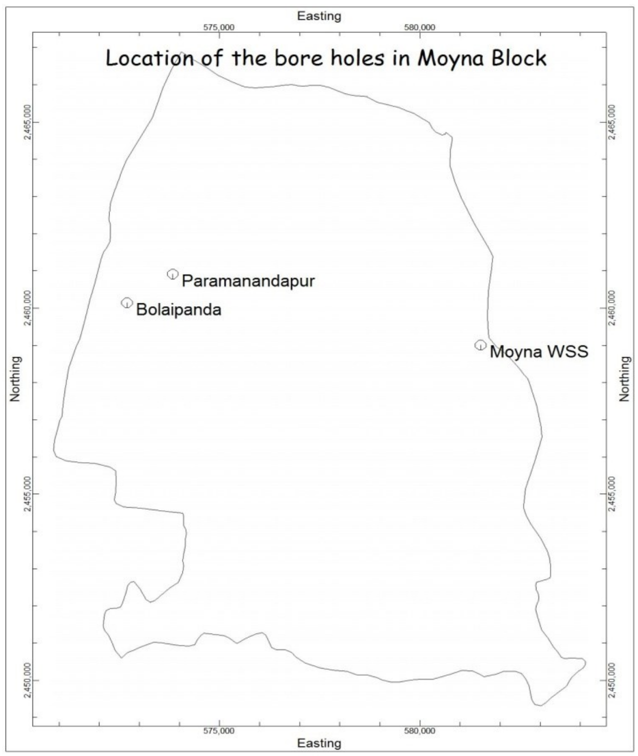
Table 14.6 CCA Created by Different Sources in the block (2013-14)

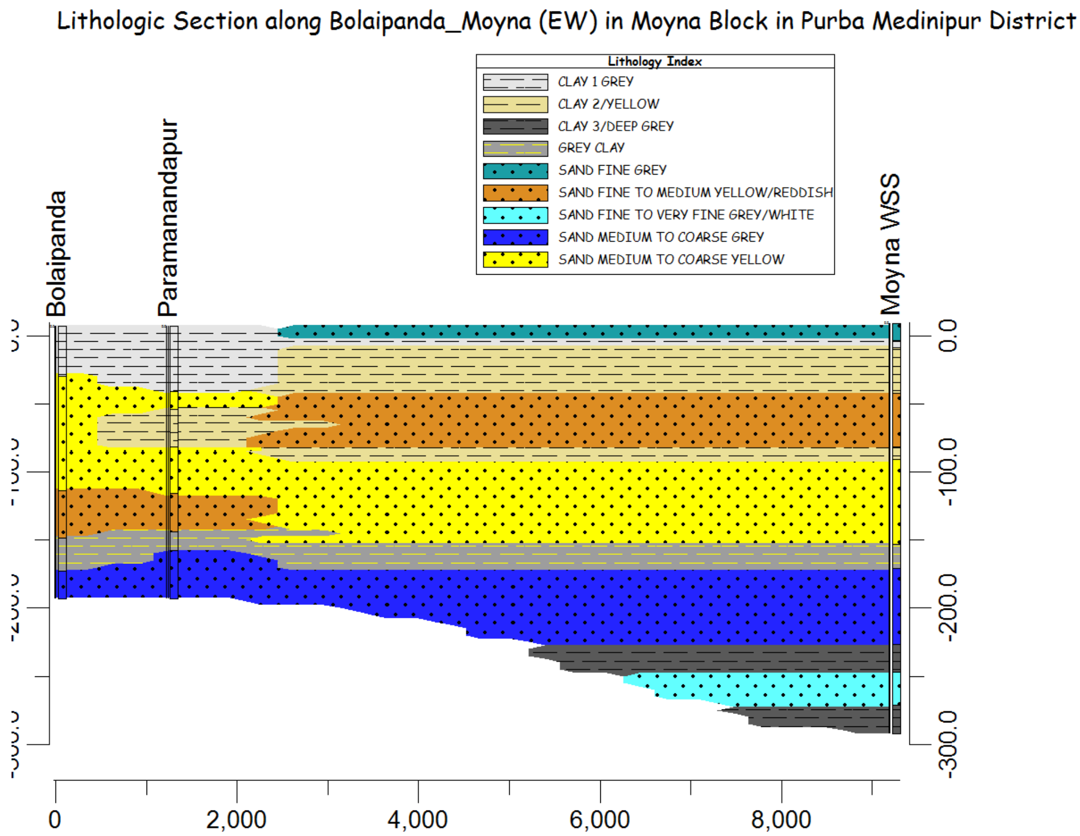
Block Name	Dugwell		Shallow Tubewell		Medium Tubewell		Deep Tubewell		Surface Flow		Surface Lift		CCA(ha.) Total CCA(ha.)		
	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	Ground Water	Surface Water	
Moyna	165.00	543.30	257.00	1568.94	1.00	20.00	15.00	172.58	260.00	1072.28	88.00	465.72	2304.82	1538.00	3842.82

14.5 Geology and Sub-Surface Geology

The block is covered by Holocene sediments. The newer alluvium of Holocene age is underlain by Piestocene Quaternary sediments. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt. Departments, the actual lithology and interpreted aquifer models are prepared and aquifer systems has been classified.

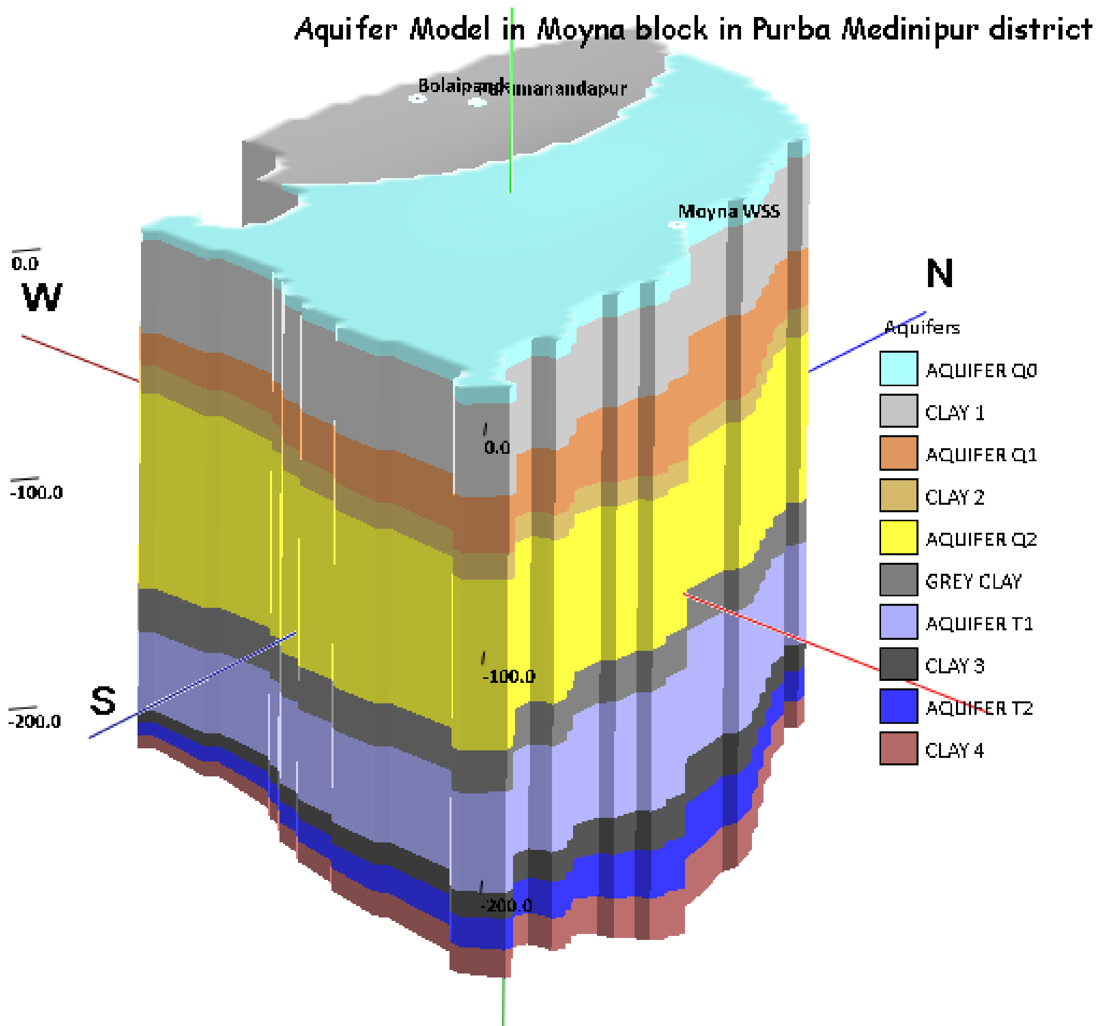

W


Location of the bore holes in Moyna Block
Easting
575,000
580,000
Northing
2,465,000
2,460,000
2,455,000
2,450,000
Paramanandapur
Bolaipanda
Moyna WSS



The lithology model reveals that the block is overlain by thick surface clay of 30-40 m thick. However, in the eastern and central parts of the block thin find sand layers are found. The surface clay is gray and yellow in colour representing younger and older alluvium. The lithology is represented by alternate sequence of sands of fine to medium and coarse and clay. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and tertiary boundary is marked by occurrences of thick gray clay. Tertiary gray clay is thick (20 m) and consistent and is found to occur at an average depth of 150-170 mbgl. In Moyna block the cumulative thickness of quaternary sediment is more than that of Tertiary sediments.

14.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:


Aquifer Model in Moyna block in Purba Medinipur district
Bolaipanda
Paramanandapur
Moyna WSS
W
N
S
0.0
-100.0
-200.0
Aquifers
AQUIFER Q0
CLAY 1
AQUIFER Q1
CLAY 2
AQUIFER Q2
GREY CLAY
AQUIFER T1
CLAY 3
AQUIFER T2
CLAY 4

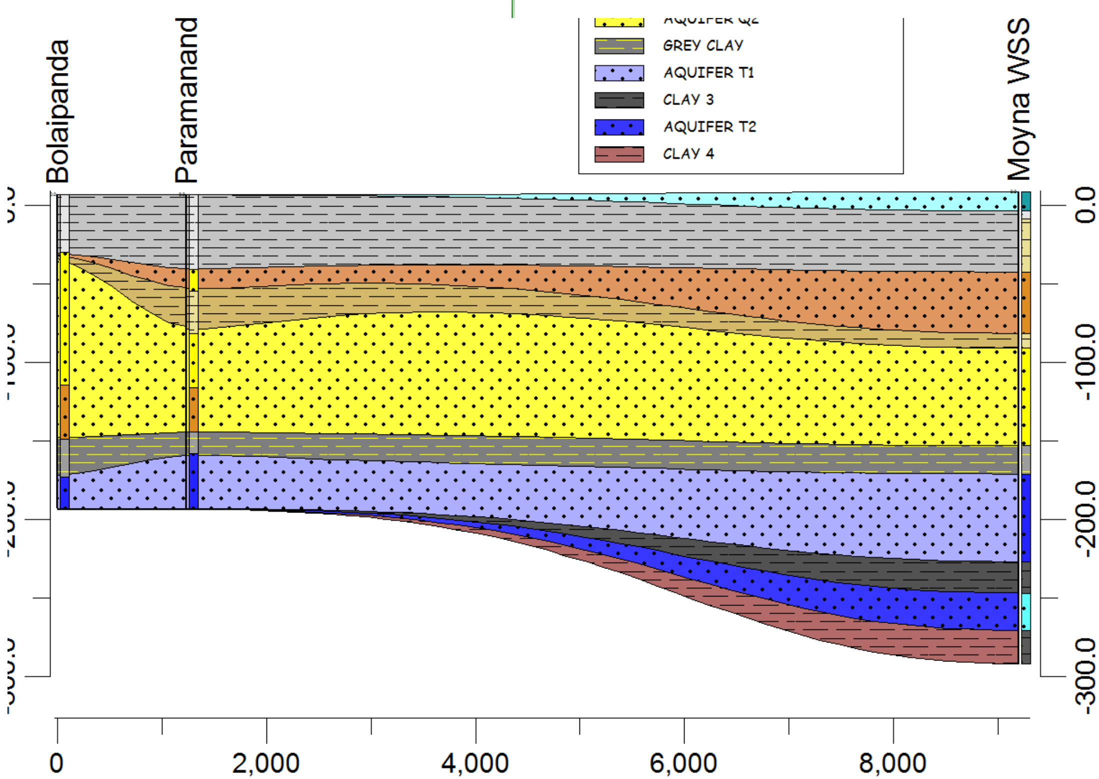

Bolaipanda
Paramanand
Moyna WSS
GREY CLAY
AQUIFER T1
CLAY 3
AQUIFER T2
CLAY 4
0.0
-100.0
-200.0
-300.0
0
2,000
4,000
6,000
8,000

Table 14.7 Disposition of Aquifers and Q/T Boundary In Tamluk Block

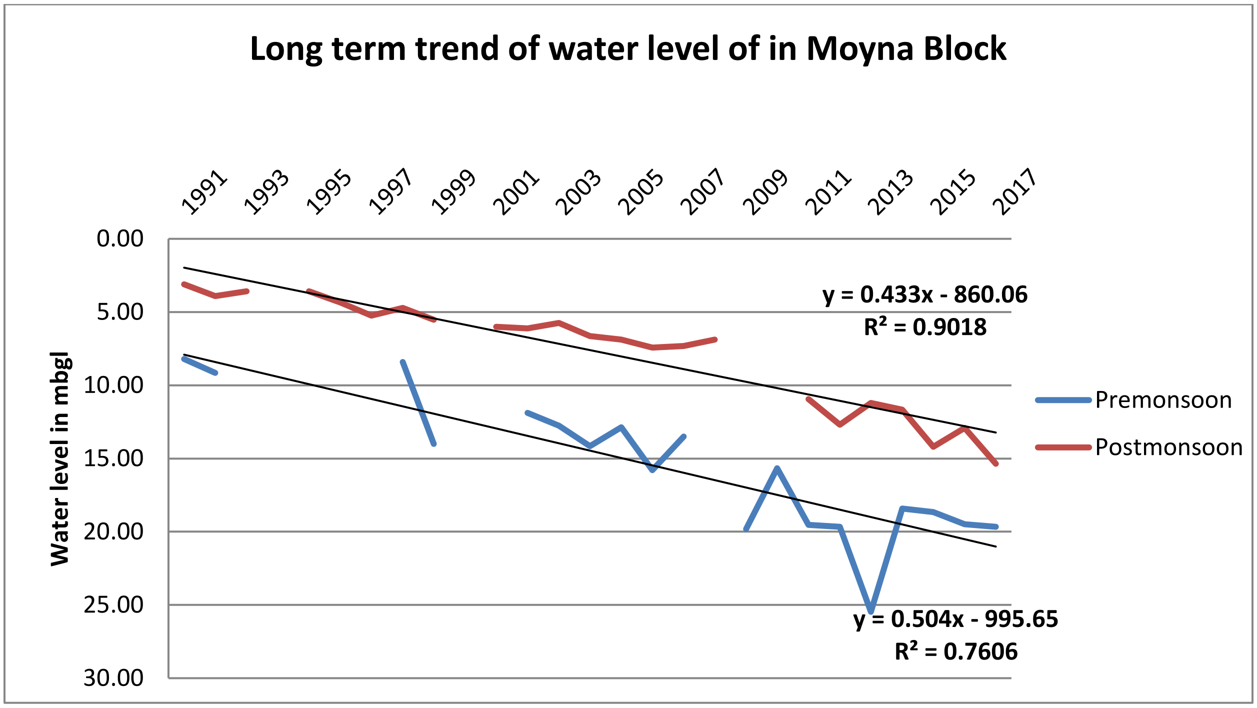
Block	Quaternary Aquifers						Q/T Boundary			Tertiary Aquifers					
	Q1			Q2						T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Moyna	44.95	62.43	26.22	75.00	156.00	81.00	156.00	175.00	19.00	175.00	212.00	37.00	218.67	226.67	24.00

The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. The cumulative thickness of Tertiary aquifer in the area is less (60 m) than that of quaternary aquifers (105 m). Both the Quaternary and Tertiary aquifers are fairly thick and consistent throughout the block. .

Ground Water Condition

Groundwater, in both quaternary and tertiary aquifer system is under confined condition. Pre and post monsoon water level have been monitored from observation wells in Quaternary and Tertiary aquifer systems. The data of CGWB and SWID has been compiled and long-term water level 2002-2017 has been analysed from SWID data for both aquifers. It is observed that Quaternary aquifer in the area registers a long-term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow from NW-SE and NE-SW from 6 m below sea level to 9 m below sea level in Quaternary aquifer and 12 to 14 m below sea level in Tertiary aquifers. The ground water flow is influenced by local ground water development in the block.

Aquifer system	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m below msl)
Tertiary	10	20.3-21.1	12.4-13.5			-14 m
Quaternary	4	19	12.3	50 cm fall	43 cm fall	-6 to -9 m


Long term trend of water level of in Moyna Block
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Water level in mbgl
y = 0.433x - 860.06
R² = 0.9018
y = 0.504x - 995.65
R² = 0.7606
Premonsoon
Postmonsoon

Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is about 111-125 m^3/hr with moderate drawdown of 4-5 m. The specific capacity ranges between 21-27 m^3/hr/m drawdown. Irrigation shallow tube wells in the quaternary aquifer is rare.

***Aquifer* Wise Ground Water Resource Availability**

The entire block is mostly under confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl, therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area. The available resource both in Quaternary and Tertiary aquifers have been estimated separately. It has also been estimated that 0.53 MCM of water flows across the Tertiary aquifers in the block.

Table 14.8 Details of resource available in Moyna Block (in MCM)

Resource Availability	Tertiary in MCM	Quaternary
Resource by Storage	8.0786	2.5422

Table 14.9 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in ($m^{2/}$day)	Annual Flow in MCM
Moyna	12.00	0.000060	2000.00	0.53

14.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from Tertiary aquifers the following chemical parameters are detected in Moyna block.

Table 14.10 Results of Chemical analysis of Tertiary aquifer in Moyna

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO_3	HCO_3	TA as CaCO3	Cl	SO_4	NO_3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO_4	Fe
1	Dakhin moyna	Moyna	Tertiary	8.05	909	bdl	329	270	107	22	12	10	2	150	133	11.7	1.9	0.43
2	Paramananda pur vivekananda bidya pith	Moyna	Tertiary	7.84	710	bdl	354	290	32	25	21	20	6	125	108	11.7	2.6	bdl
3	Paramananda pur wss	Moyna	Tertiary	7.96	483	bdl	183	150	25	25	13	32	15	120	48	7.8	2	0.31

The water from Tertiary is fresh. The concentration of Fe in ground water is slightly higher than the permissible limit. The water is mostly sodium bi-carbonate water.

14.8 Ground Water Resource Enhancement and Management Plan:

14.8.1 Ground Water Management Plan for drinking purposes

PHED, Govt. of West Bengal is entrusted for supply of drinking water in the block. Besides spot sources of hand pumps, mark II tube wells, PHED has so far commissioned 3 no ground water based water supply schemes and 1 more ground water based scheme is under commissioning in the block. It has been assessed that total covered population through these schemes is about 61164. Therefore, 165763 remaining population need to be brought under water supply schemes for which about 2.4201 MCM water is required. As per the quality of the drinking water standard and prevailing practices of water supply in the block the 40% of the demand is met from Quaternary and 60% from Tertiary aquifer. Considering the average discharge of the individual aquifers 7 tube wells in Quaternary and 5 tube wells in quaternary has been proposed. Therefore, further development of this aquifer will definitely affect the ground water regime in the area. It is observed that the probable decline of piezometric surface is 17 m and 25 m in Quaternary and Tertiary aquifers respectively. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation should always be compensated by construction of suitably design artificial recharge structures in respective aquifers.

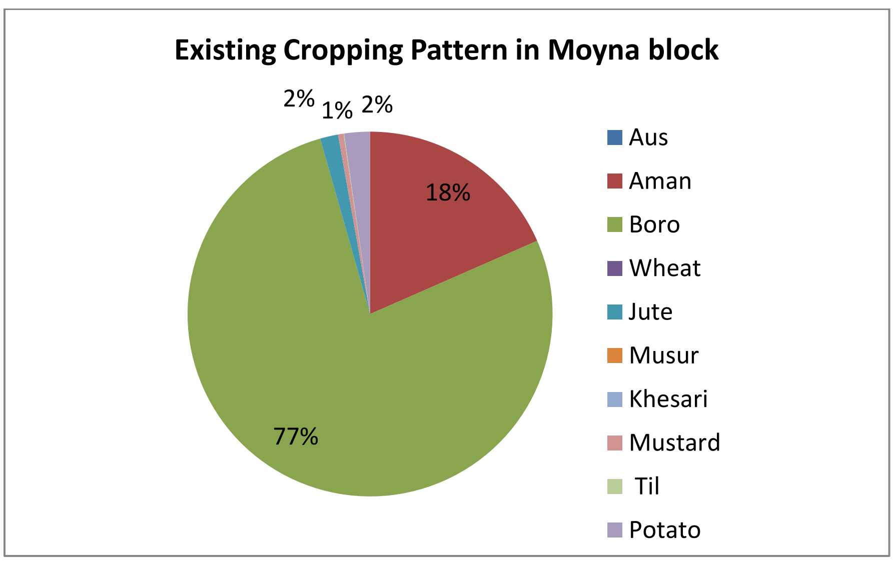
Table 14.11 Development Proposal of Tertiary Aquifers with implication on Piezometric Surfaces of Each Aquifer

Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncove	Annual resource proposed to be utilized from Quatern	Annual resource proposed to be utilize	Total annual unit draft of one TW in MCM (considering	Total annual unit draft of one TW in MCM (considering	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquife	Decline of piezometric surface in Quaternary	Decline of piezometric surface in Tertiary aquifer(

		red populat ion @40lpc d in MCM	ary Aquifer in MCM	d from Tertiar y Aquife r in MCM	average discharg e of Quatern ary and 8 hrs/day running)	average discharg e of Tertiary and 8 hrs/day running)		r	Aquifer (in m)	in m)
Moy na	158.69	2.4201	0.9681	1.4521	0.1314	0.2628	7	5	17.14	25.7

14.8.2 Management Plan for irrigation:

Present cropping pattern in the block: The major crop in the block is boro paddy which accounts for 77% of total crops in the block, other includes rain fed aman paddy (18%) and limited wheat, jute , mustard and potato cultivation.



The cultivable area of the block is 11063 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA in the block is 3843 ha. Further, 7220 ha area is to be brought under irrigation coverage in the blocks. The irrigation tube wells are common in the block. However, most of the existing irrigation tube wells are concentrated within the depth range of 100 m depth and rest lies within 100-200 m depth.

Both the Quaternary and the Tertiary aquifer in the block is being utilized for irrigation uses through construction of shallow and deep tube wells. The aquifers are under semi confined to confined condition and witnesses steady decline of water level both in pre and post monsoon time. Therefore, further development of irrigation tube wells is not recommended. In contrary to these the trivial modification of cropping pattern may bring more area under irrigation in the blocks, therefore increases the intensity of cropping. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 1080 ha m of water. This volume of water is used to cultivate oilseeds (sunflower/ mustard), potato etc. as per the prevailing cropping pattern in the block. **Thus, 598.80 ha effective increase in irrigation area** may be created by change in cropping pattern. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability.

Table 14.12 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					**Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation**				**Increase in area under Irrigation coverage by reducing 10% boro Cultivation**	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction(ha)	Volume of Irrgation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Potato(Delta factor:60 cm)	Floriculture (Bell, Merrigold, tuberose) (Delta factor:22.5 cm)	Total additional area created in ha	Effective Increase in area(ha)
Moyna	**8997**	**1.2**	**8097**	**1080.00**		**899.10**	**599.40**		**1498.50**	**598.80**

14.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non-committed surface runoff produced in the block is 24.3563 MCM. The non-committed flow is proposed to be utilized to recharge the depleted Quaternary and Tertiary aquifers in the block. As per the available storage space 0.5981 MCM and 0.5837MCM water is required to fill the available storage space in Tertiary and quaternary aquifers in the block respectively. Therefore, 45 and 44 injection wells with roof top rainwater harvesting structures is recommended in the rural area of the blocks in the respective Tertiary and Quaternary aquifer. The successful implementation of recharge structures may raise the piezometric surface about 10 m. Further, in case of construction of more tube wells in Tertiary and Quaternary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated.

The balance non committed runoff (after utilizing to fill up the depleted aquifers in the block) is estimated as 23.1746 MCM which is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 463 storage / irrigation tanks have been proposed. These tanks can generate additional irrigation potential of 3476 ha considering average delta factor of 50 cm for rabi crops, vegetable, horticulture/ floriculture crops. Therefore, by change in cropping pattern and utilizing the non-committed runoff for tank irrigation total 4075 ha further irrigation potential can be created. Thus, 58% of the uncovered area in the block may be brought under irrigation. The roof top rainwater harvesting structures with suitably design injection wells may be proposed to construct in the town area in primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with 1-2 irrigation tanks for harvesting of surface runoff at suitable locations and for subsequent irrigation uses.

Summary of Management Plan:

- *Drinking water tube wells have been recommended both in Quaternary and Tertiary aquifer to meet the uncovered demand from ground water sources. Thus 12 drinking water tube wells, 7 in Quaternary and 5 in Tertiary aquifer have been proposed.*
- *The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of injection wells with roof top harvesting arrangements. Thus 45 injection wells in Tertiary and 44 injection wells in Quaternary have been proposed.*
- *Further construction of irrigation tube wells is restricted. The boro area may be reduced by 10% of existing area, and the surplus water may be used to irrigate pulses, oilseed and floriculture crops. Thus additional 599 ha irrigation potential can be generated.*
- *The non-committed runoff may be used for irrigation tanks. Considering capacity of one tank as 0.05 MCM, 463 irrigation tanks are proposed, preferably one- two in each habitation in the block. This will generate additional irrigation potential of 3476 ha. Thus, the additional irrigation potential created by change in cropping pattern and by harvesting surface runoff will bring 58% of the remaining cultivable area in the block under irrigation coverage.*

Table 14.13 Proposed Conservation and Recharge Structures based on the available non committed surface runoff and available storage space

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Vol of water kept for conservation/storage tanks in MCM (3-(4+5))	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks (6/8)	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary (4/9)	No of RTRWH with injection well required for Quaternary (5/9)

Moyna	158.69	24.36	0.5981	0.5837	23.1746	0.05	463	0.0133072	45	44

15.0 MANAGEMENT PLAN OF NANDAKUMAR BLOCK

15.1 Location, Demography and Rainfall

Nandakumar block is a part of Tamluk subdivision. Nandakumar is located at 22.1963°N latitude and 87.9207 °E longitude Bounded in the east by Mahisadal Block and Runarayan River, in the north by Tamluk block, in the west by Moyna block and in south by Haldi river and Chandipur block of Purba Medinipur district.

- Subdivision: Tamluk
- Sub basin: Rupnarayan and Haldi
- Geographical Area: Nandakumar 165.70 sq km.
- Population (2011 Census)

Table 15.1 Total population of the Block

	Rural Population	Urban Population	Total
Block	262998	---	262998

The block comprises 12 Gram Panchayets, 106 villages, 212 habitations and 58450 households.

Table 15.2 Basic Demographic Detail of Nandakumar Block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	HouseHolds	Population
1	Bargoda Godar	8	19	5364	23489
2	Basudevpur	10	20	7325	32204
3	Byabattarhat Paschim	11	24	3883	17381
4	Byabattarhat Purba	13	24	4746	21428
5	Chak Simulia	11	15	4202	18744
6	Dakshin Narikelda	12	14	4744	20498
7	Kalyanpur	7	16	3794	16613
8	Kumorara	12	20	6028	26588
9	Kumrchak	8	17	5407	23234
10	Saoraberia Jalpai-i	4	15	3118	14064
11	Saoraberia Jalpai-ii	4	14	6076	27708
12	Sitalpur	6	14	3763	17055

	Paschim				

Source: PHED, Govt. of WB, Website

- **Normal Annual Rainfall** in the district: 1663.40 mm

Table 15.3 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall
Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

15.2 Physiographic and Drainage:

The block is a part of lower Gangetic plain and is a part of Rupnarayan and Haldi sub-Basin. The river Rupnarayan is flowing in the northern parts of the block whereas Haldi flowing in southeast direction marks the southern boundary of Nandakumar block. The Haldi and its drainage channels to some extent witnesses' tidal influences. The average elevation is 4-5 m amsl. The dominant soil type of the block is very poorly drained impermeable clayey soil. The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

15.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 15.4 Details of Land use pattern of block (area in ha)

Name of the block	Reporting area	Forest area	Area under non-agriculture wastes	Barren and un-culturable lands	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Net area sown
Nandakumar	16469	0	4349			54				12066

15.4 Agriculture and Irrigation:

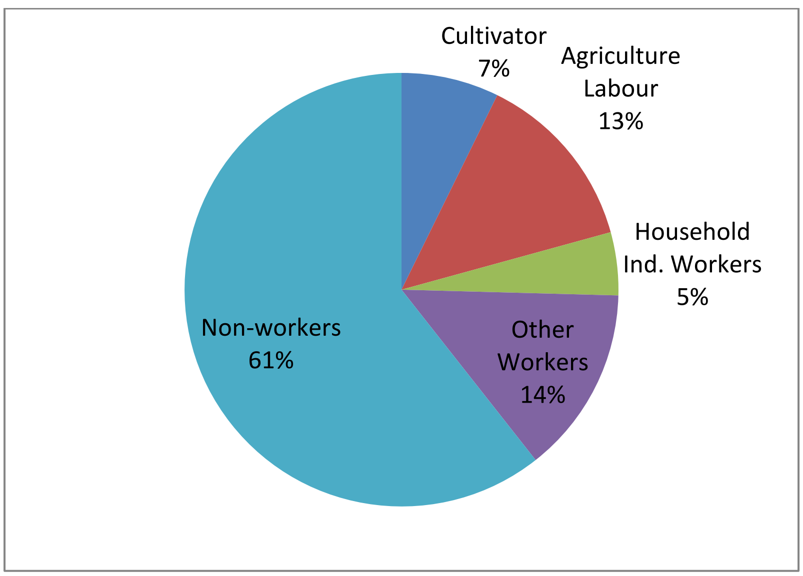


Table 15.5 Distribution of persons engaged in agriculture and other workers/non workers in the Block

In Nandakumar block, 61% of total population is non workers. It is evident from the above diagram that 20% of the total population in the block is engaged in agriculture either as cultivator or as agriculture labour.5% comprises Household industrial workers and 14% comprises other worker.

Cultivable area in the block is 12120 ha. Irrigation in the block is achieved by surface and ground water sources. The Culturable Command area (CCA) created by surface water and ground water resources in the block is 4286.95 ha which is far less than the total cultivable area in the block. 86% of the irrigation coverage achieved by surface water and the rest 14% by ground water sources. Due to the brackish nature of ground water in shallow aquifer the irrigation development from ground water resources is very limited in Nandakumar block. Attempt may be initiated to bring further area under cultivation in the block.

Surface irrigation network comprises canal irrigation, tanks, surface flow and lift irrigation. As per the District Statistical Handbook, 2014, 300 ha have been brought under irrigation through canal. A considerable area is brought under irrigation by numbers of tanks. Surface flow, lift irrigation comprises other mode of surface irrigation networks in the block.

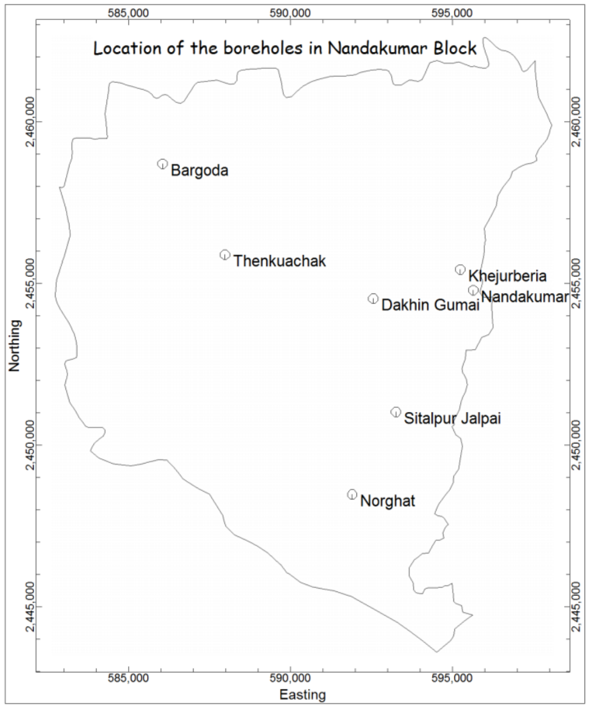
Ground water irrigation is limited and is accomplished through limited numbers of shallow tube wells and deep tube wells. The CCA created by about 48 shallow tube wells is 434 ha, besides that some more area is under irrigation through medium and deep tube wells.

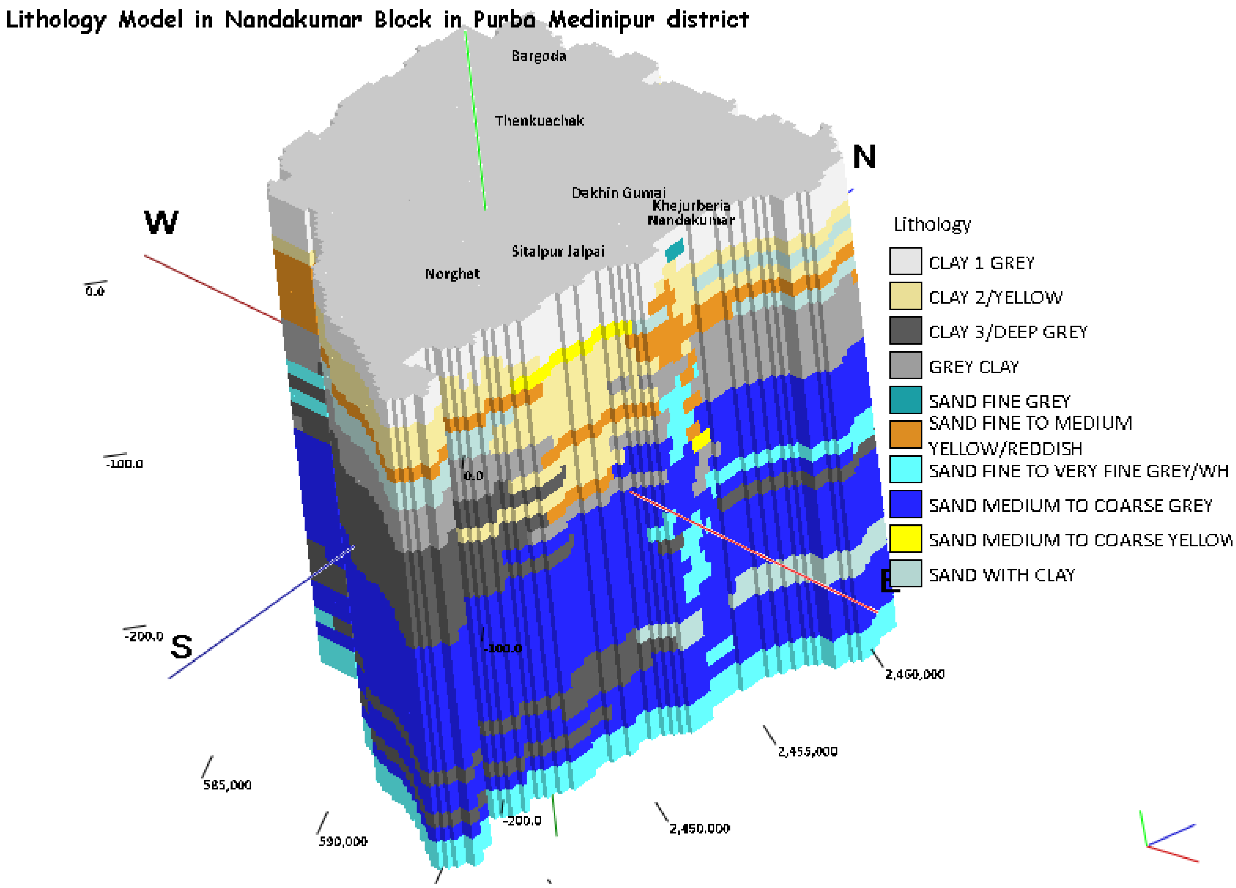
Table 15.6 CCA Created by Different Sources in the block (2013-14)

Block Name	Shallow Tubewell		Medium Tubewell		Deep Tubewell		Surface Flow		Surface Lift		CCA(ha.) Total CCA(ha.)		
	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	Ground Water	Surface Water	Total
Nandakumar	48.00	434.22	0.00	0.00	4.00	160.00	51.00	565.97	236.00	3126.76	594.22	3692.73	4286.95

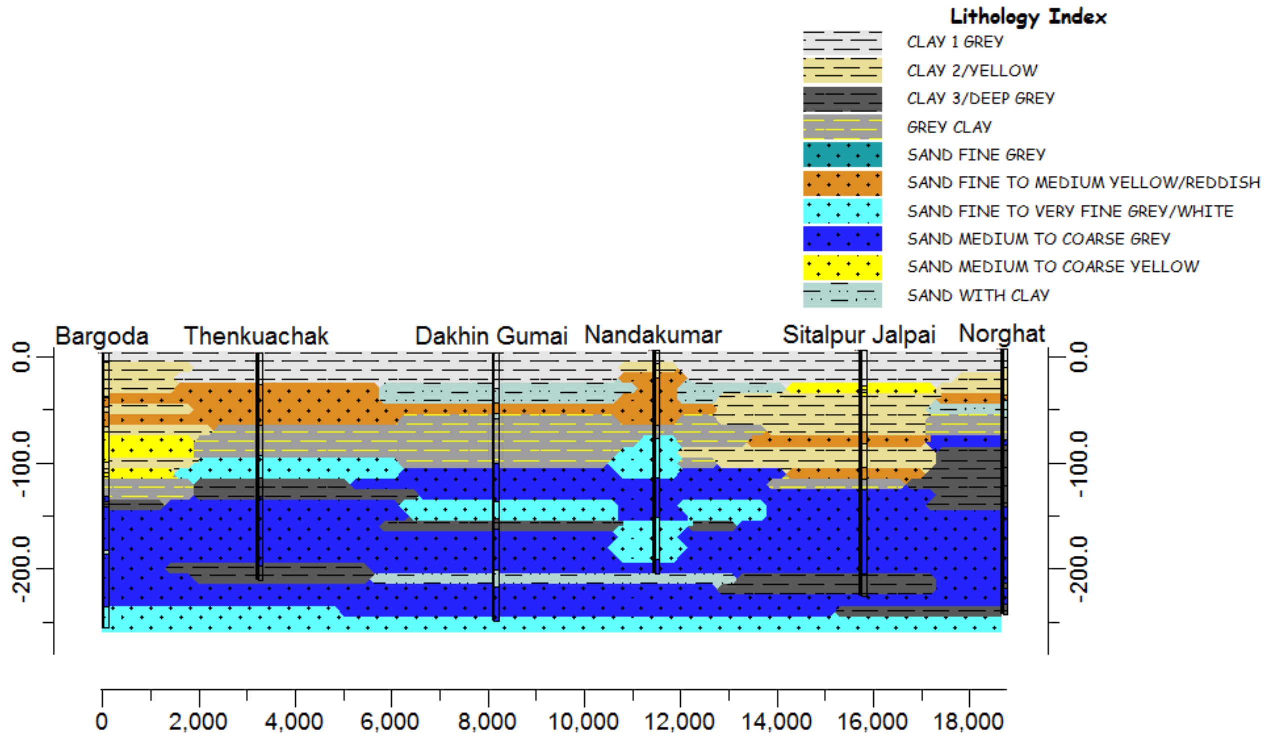
15.5 Geology and Sub-Surface Geology

The block is covered by Holocene sediments. The newer alluvium of Holocene age is underlain by Pleistocene Quaternary sediments. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt. Departments, the actual lithology and interpreted aquifer models are prepared and aquifer systems has been classified.



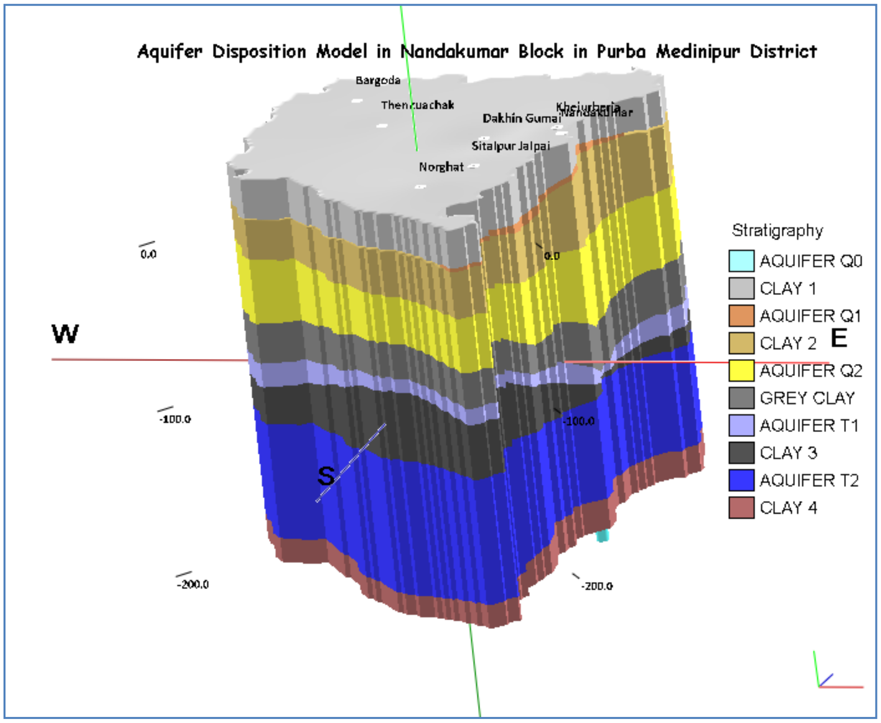

Lithology Model in Nandakumar Block in Purba Medinipur district
Bargoda
Thenkuachak
Dakhin Gumai
Khejurberia
Nandakumar
Sitalpur Jalpai
Norghat
W
N
S
E
0.0
-100.0
-200.0
Lithology
CLAY 1 GREY
CLAY 2/YELLOW
CLAY 3/DEEP GREY
GREY CLAY
SAND FINE GREY
SAND FINE TO MEDIUM YELLOW/REDDISH
SAND FINE TO VERY FINE GREY/WH
SAND MEDIUM TO COARSE GREY
SAND MEDIUM TO COARSE YELLOW
SAND WITH CLAY
2,460,000
2,455,000
2,450,000
585,000
590,000

Lithological Section along Bargoda-Nandakumar-Norghat Section in Nandakumar block



The lithology model reveals that the block is overlain by thick grey to yellow surface clay of 22-25 m thick. The lithology is represented by fine to very fine grey sands, medium to coarse yellow to gray sands with intervening gray to yellow and dark gray clay. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and Tertiary boundary is marked by occurrences of thick gray clay. The depth of occurrences of Tertiary clay is variable with shallowest is at Norghat area. The average depth of Tertiary clay in Nandakumar block is 92-117 m. The average thickness of the Tertiary clay is 24 m.

15.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:



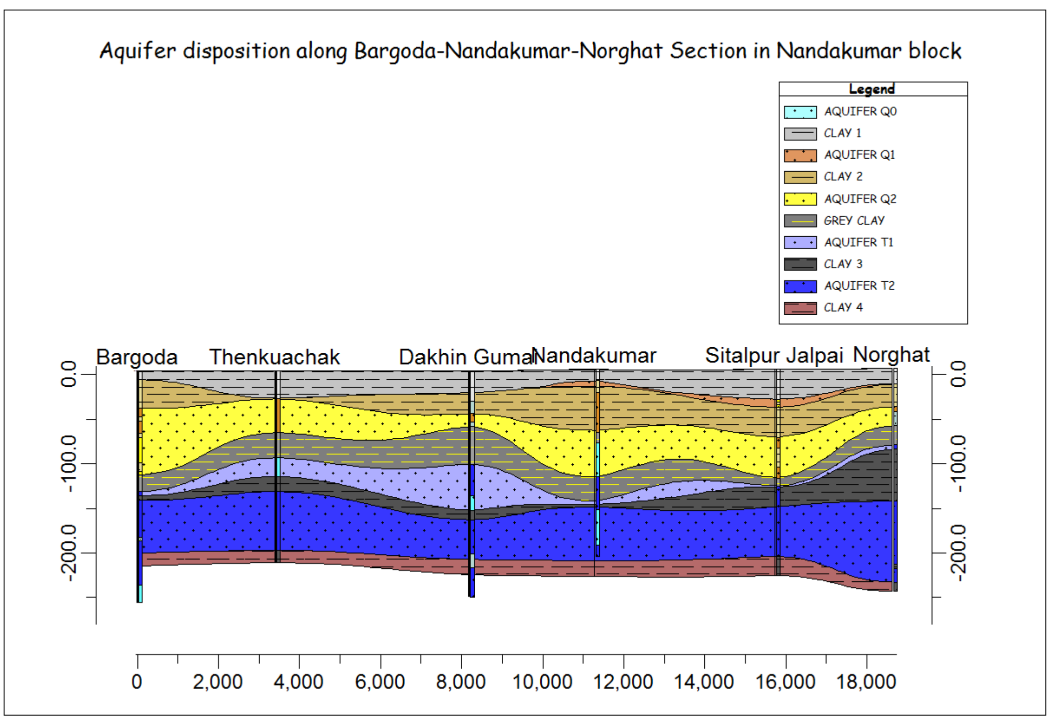


Table 15.7Disposition of Aquifers and Q/T Boundary in Nandakumar Block

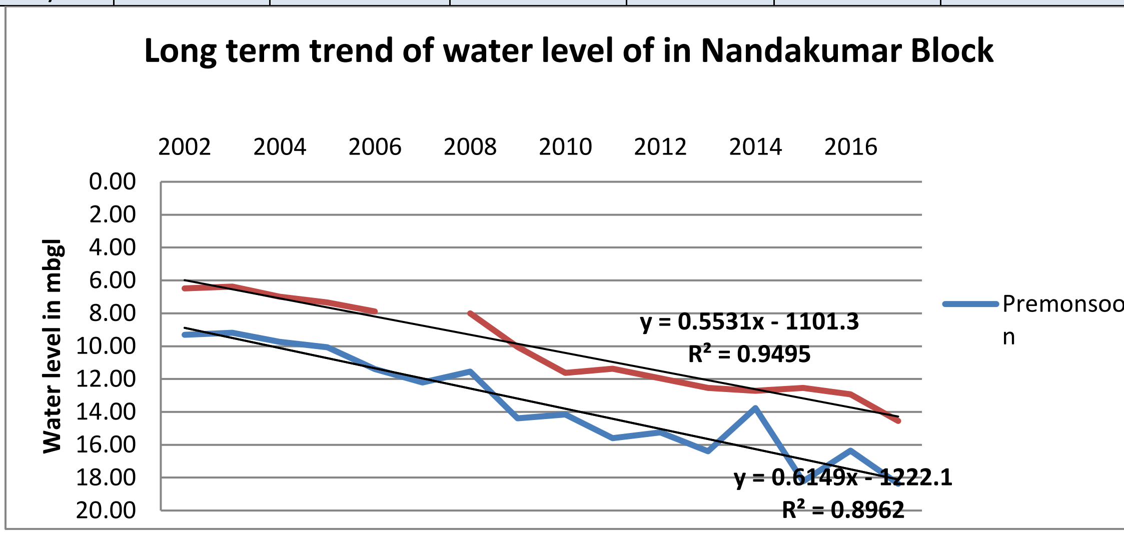
Block	Quaternary Aquifers						Q/T Boundary			Tertiary Aquifers					
	Q1			Q2						T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Nandakumar	22.43	25.35	3.51	51.50	92.50	41.00	92.50	117.33	24.83	117.33	131.50	14.17	146.83	235.67	88.83

The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. Along Bargoda-Norghat section the individual aquifer system is disposed uniformly with local variation of thickness of individual layers. The 1st Quaternary aquifer (Q1) is insignificant and is represented at few locations only. The Quaternary aquifer in the block is principally represented by thick (40 m) continuous older alluvium sands. The Q/T boundary clay is thick consistent throughout the block. The cumulative thickness of Tertiary aquifer is more about 100 m within the depth of 300 m is far more than that of Quaternary aquifers. The T1 is found to narrowed at few places.

Ground Water condition

Ground water, in both quaternary and tertiary aquifer system is under confined condition. Pre and post monsoon water level have been monitored from number of observation wells in Tertiary aquifer systems. The depth of the wells varies between 182-236 m. Due to the paucity of the working tube wells in the quaternary aquifer, the monitoring data from the quaternary aquifer system was inadequate. The data of CGWB and SWID has been compiled and long term water level 2002-2017 has been analyses from SWID data for Tertiary aquifer only. It is observed that Tertiary registers a long term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow from NW to SE and 11.65 m below sea level to 14.30 m below sea level in Tertiary aquifers. The ground water flow is influenced by local ground water development in the block.

Aquifer system	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m below msl)
Tertiary	8	16.8-19.30	12.30-15.30	61 cm fall	55cm fall	-11.65 to -14.30 m



Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is about 72-140 m^3/hr with moderate drawdown of 2.28-5.36 m. The specific capacity ranges between 13.5-48 m^3/hr/m drawdown. The Irrigation tube wells are not very common in Nandakumar block.

***Aquifer* Wise Ground Water Resource Availability**

The entire block is under confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl, therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area.

Table 15.8 Details of resource available in Tertiary aquifer (in MCM) in Block

Resource Availability	Nandakumar block
Resource by Storage	11.11

Table 15.9 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in (m^2/day)	Annual Flow in MCM
Nandakumar	16.67	0.000265	2000.00	3.23

15.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from Tertiary aquifers the following chemical parameters are detected in Nandakumar block.

Table 15.10 Results of Chemical analysis of Tertiary aquifer in Nandakumar

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO_3	HCO_3	TA as CaCO3	Cl	SO_4	NO_3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO_4	Fe
1	Bargodagodar	Nandakumar	Tertiary	7.72	1476	bdl	372	305	256	2	18	36	21	225	200	15.6	3.4	0.34
2	Khejurberia	Nandakumar	Tertiary	7.95	2655	bdl	519	425	622	0	14	12	2	490	350	50.7	3.8	4.52
3	Sitalpur jalpai	Nandakumar	Tertiary	8.06	2183	bdl	470	385	462	0	0	44	9	440	260	42.9	4.5	bdl
4	Thenkuachak	Nandakumar	Tertiary	8.16	1253	bdl	315	384	178	35	43	58	9	180	202	23	5.8	1.24

The water from Tertiary is fresh to brackish and the EC varies between 1253-2655 **µS/cm**. The concentration of Fe in ground water is reported high at Khejurberia and Thenkuachak area. The water is mostly sodium chloride and sodium bi-carbonate water.

15.8 Ground Water Resource Enhancement and Management Plan:

15.8.1 Ground Water Management Plan for drinking purposes

PHED, Govt. of West Bengal is entrusted for supply of drinking water in the block. Besides spot sources of hand pumps, mark II tube wells PHED has so far commissioned 5 no ground water-based water supply schemes and 3 more ground water based schemes are under commissioning in the block. Besides that, a surface water based schemes has been designed for the population of Nandigram I& II, Chandipur and Nandakumar block. It has been assessed that total covered population through the commissioned schemes is about 171374. Therefore, 91624 remaining population need to be brought under water supply schemes for which about 1.3377 MCM water is required. As per the prevailing practices in the block the Tertiary aquifer may be utilized to cater the remaining need of drinking water supply in the block. Thus, 5 drinking water tube wells in Tertiary aquifer may further be constructed in phases to meet the demand from ground water resources. Therefore, further development of this aquifer will definitely affect the ground water regime in the area. It is estimated that the probable decline of piezometric surface in Tertiary aquifer as an impact of installation of additional tube wells would be 11.87m. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation should always be compensated by construction of suitably design artificial recharge structures in respective aquifers.

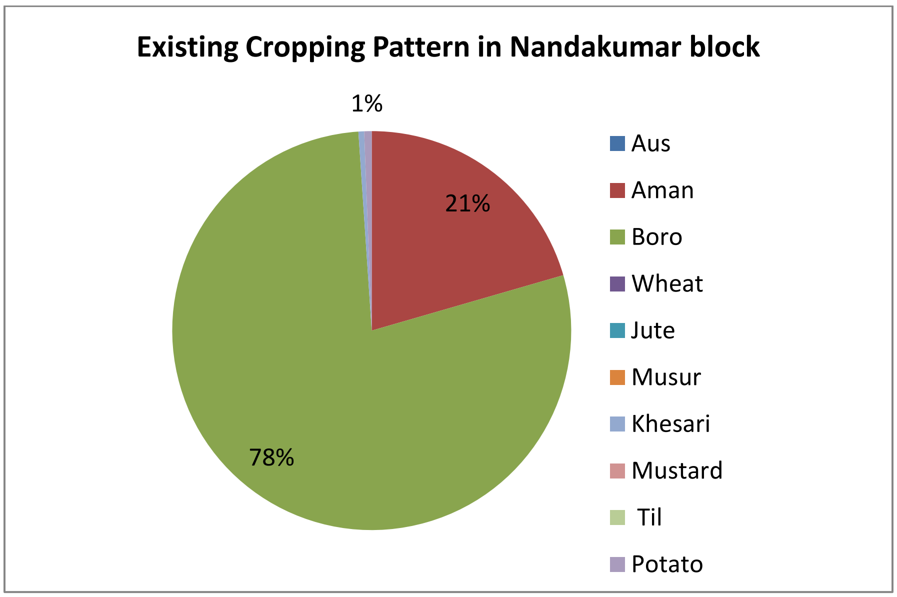
Table 15.11 Development Proposal of Tertiary Aquifers with implication on Piezometric Surfaces of Each Aquifer

Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncovered population @40lpcd	Annual resource proposed to be utilized from Quaternary Aquifer in	Annual resource proposed to be utilized from Tertiary Aquifer	Total annual unit draft of one TW in MCM (considering average discharge of Quaternary	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary and	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquifer	Decline of piezometric surface in Tertiary aquifer(in m)

		in MCM	MCM	in MCM	and 8 hrs/day running)	8 hrs/day running)			
Nandakumar	165.7	1.3377	0.0000	1.3377		0.2628	0	5	11.87

15.8.2 Management Plan for irrigation:

Present cropping pattern in the block: The major crop in the block includes Aman and Boro paddy. Boro includes 78% of cropped area. The other minor crops include Potato and Khesari.



The cultivable area of the block is 12120 ha. The culturable command area (CCA) has been created by mainly by surface irrigation networks and limited area by ground water. Total CCA in the block is 4287 ha and therefore, 7833 ha area to be brought under irrigation coverage for which diversification in cropping pattern has been proposed.

The quaternary aquifer in the block is reported to be brackish to saline in nature and in general not developed at all for irrigation uses. Tertiary aquifers in the block are under semi confined to confined condition and witnesses steady decline of water level therefore, further development of irrigation tube wells is not recommended. In contrary to these the trivial modification of cropping pattern may bring more area under irrigation in the blocks. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 1119.60 ha m of water. This volume of water is used to cultivate oilseeds (sunflower/ mustard), pulses, potato etc. as per the prevailing cropping pattern in the block. **Thus, 1863.50 ha effective increase in irrigation area** may be created by change in cropping pattern. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability.

Table 15.12 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation				Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction (ha)	Volume of Irrigation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor:30 cm)	Potato (Delta factor:60 cm)	Total additional area created in ha	Effective Increase in area(ha)
Nandakumar	9327	1.2	8394	1119.60		932.07	1242.76	621.38	2796.20	1863.50

15.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non-committed surface runoff produced in the block is 25.4323 MCM. The non-committed flow is proposed to be utilized to recharge the depleted Tertiary aquifers in the block. As per the available storage space 1.1102 MCM water is required to fill the available storage space in tertiary aquifers in block. Therefore, 83 injections well with roof top rainwater harvesting structures are recommended in the block. The successful implementation of recharge structures may raise the piezometric surface about 9-10 m. Further, in case of construction of more tube wells in

Tertiary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated.

The remaining non committed runoff, 24.3221 MCM is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 486 storage tanks have been proposed. These tanks can generate additional irrigation potential of 3648.32 ha considering average delta factor of 50 cm for rabi crops, vegetable, horticulture/ floriculture crops or the storage tanks may be utilized for other purpose like pisciculture etc. The roof top rainwater harvesting structures with suitably design injection wells may be proposed to construct in the census town area in primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with 1-2 irrigation tanks for harvesting of surface runoff at suitable locations and for subsequent irrigation/aquaculture uses.

Summary of Management Plan:

- *Drinking water tube wells have been recommended in Tertiary aquifer to meet the uncovered demand from ground water sources. 5 drinking water tube wells in Tertiary have been proposed.*
- *The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of 83 injection wells in block with roof top harvesting arrangements.*
- *Further construction of irrigation tube wells is restricted. The boro area may be reduced by 10% of existing area, and the surplus water may be used to irrigate pulses, oilseed and potato for more diversification of crops. Thus additional 1863.50 ha irrigation potential can be generated.*
- *The non-committed runoff may be harvested for storage tanks. Considering capacity of one tank as 0.05 MCM, 486 tanks are proposed, preferably one- two in each habitation in the block. This may generate additional irrigation potential of* 3648.32 *ha. Therefore,*

by proposed change in cropping pattern and by irrigation from tanks through harvesting of runoff 70% of the remaining area may be brought under irrigation.

Table 15.13 Proposed Conservation and Recharge Structures based on the available non committed surface runoff and available storage space

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Vol of water kept for conservation/storage tanks in MCM	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary	No of RTRWH with injection well required for Quaternary
Nandakumar	165.7	25.4323	1.1102		24.3221		486	0.0133072	83	

16.0 MANAGEMENT PLAN OF NNDIGRAM I AND NANDIGRAM II BLOCKS

16.1 Location, Demography and Rainfall

Nandigram I block is located at 22.0081 °N latitude and 87.9837 °E longitude

The block is bounded in north and north-west by Nandigram II block, in the east and southeast by Haldi river and Bay of Bengal, in the south by Khejuri II block.

- Subdivision: Haldia
- Sub basin: Kasai- Haldi
- Geographical Area: 181.84 sq km.
- Block: NANDIGRAM II
- Subdivision: Haldia
- Sub basin: Kasai- Haldi

Nandigram II is located at 22.140 °N latitude and 88.080 °E longitude

Nandigram II block is bounded in the east by Nandigram I block, in the south by Khejuri I block, in the west by Bhagawanpur II and Chandipur block and in the north by parts of Mahisadal block and Haldi river.

Geographical Area: 105.74sq km

Table 16.1 Population (2011 Census)

Block	Rural Population	Urban Population	Total
Nandigram I	202032	5803	207835
Nandigram II	117945	5274	123219

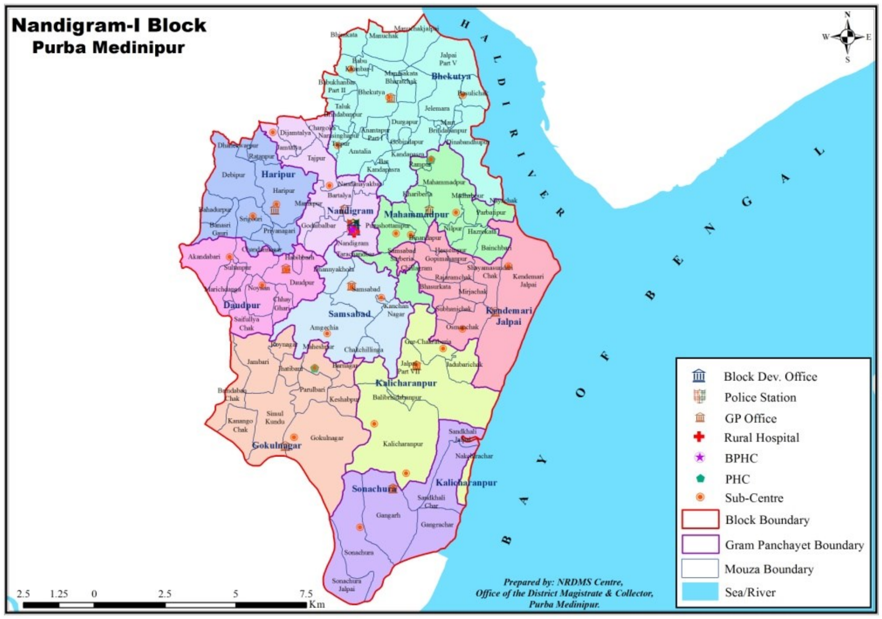


Figure 16.1 Gram-Panchayet and Mouza Map of Nandigram I block

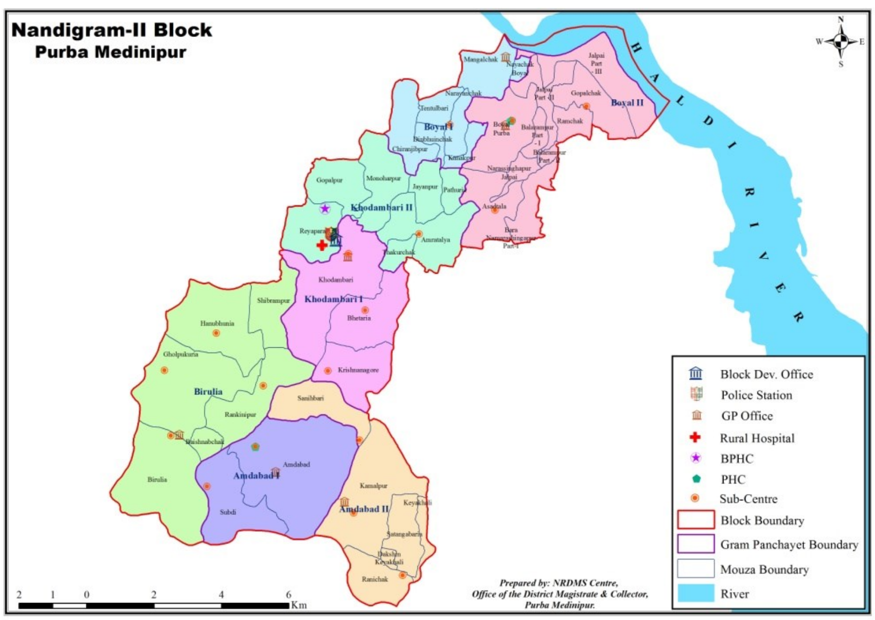


Figure 16.2 Gram-Panchayet and Mouza Map of Nandigram II block

The Nandigram I block comprises 1 census town, 10 Gram Panchayets, 99 villages, 203 habitations and 42247 households.

The Nandigram II block comprises 1 census town, 7 Gram Panchayets, 40 villages, 154 habitations and 26806 households.

Table 16.2 Basic Demographic Detail of Nandigram I block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	House Holds	Population
1	Daudpur	9	21	3885	19126
2	Gokulnagar	11	26	4232	21978
3	Haripur	9	9	3281	16127
4	Kalicharanpur	6	20	4730	23957
5	Kendimari Jalpai	11	25	5057	24680
6	Mahammadpur	13	18	4036	19621
7	Nandigram	9	14	3931	19420
8	Samsabad	5	15	3902	20173
9	Sonachura	6	16	2891	14938
10	Vekutia	20	39	6302	28345
	Total	99	203	42247	208365

Source: PHED, Govt. of WB, Website

Table 16.3 Basic Demographic Detail of Nandigram II block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	House Holds	Population
1	Amdabad-i	2	10	3487	16449
2	Amdabad-ii	5	17	3559	16813
3	Birulia	6	29	5642	25024
4	Boyal-i	8	22	3111	13903
5	Boyal-ii	9	33	3631	17679
6	Khodambari-i	3	21	3439	15935
7	Khodambari-ii	7	22	3937	17868
	Total	40	154	26806	123671

- **Normal Annual Rainfall** in the district: 1663.40 mm

Table 16.4 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall

Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

16.2 Physiographic and Drainage:

The blocks are parts of lower Gangetic plain and are parts of Kasai-Haldi sub-basin and comprises coastal block of Purba Medinipur district. Haldi river is flowing along the northern boundary of these blocks. Haldi River joins Bay of Bengal in the east of Nandigram I block. The drainage networks in the area are influenced by tidal effects. Average elevation is 5-7 m amsl. The dominant soil type of the area very poorly drained impermeable clayey soil.

The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

16.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 16.5 Details of Land use pattern of block (area in ha)

Name of the block	Reporting area	Forest area	Area under non-agriculture wastes	Barren and un-culturable lands	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Net area sown
Nandigram I	17283	0	3624	7		104				13548
Nandigram II	10721	0	1675			25				9021

16.4 Agriculture and Irrigation:

Figure 16.3 Distribution of persons engaged in agriculture and other workers/non workers

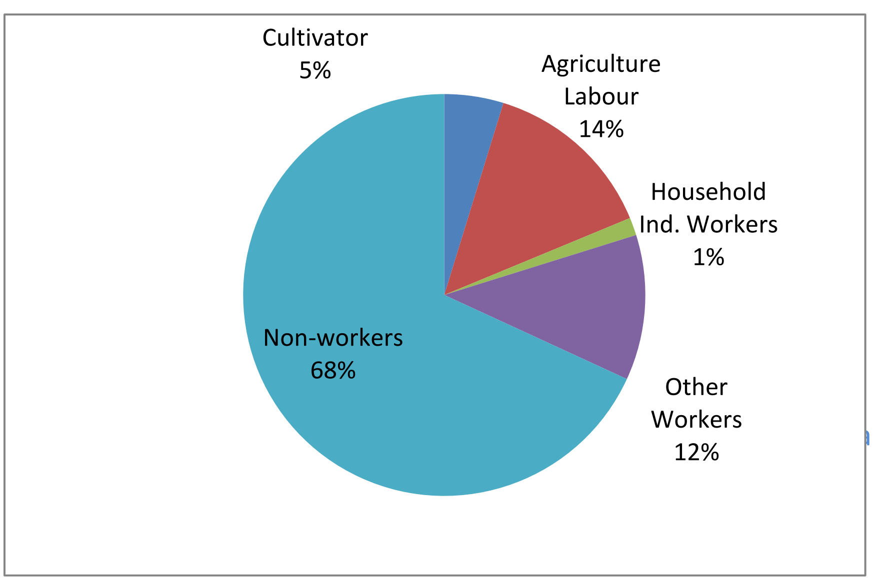
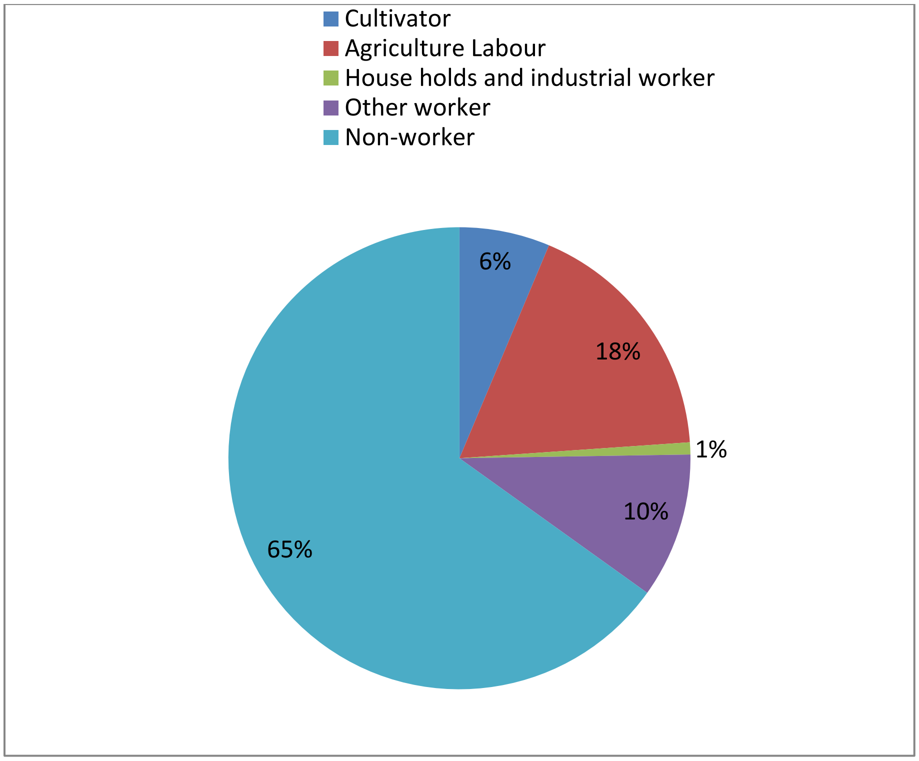


Figure 16.4 Distribution of persons engaged in agriculture and other workers/non workers



In Nandigram I block, 68% of total population is non workers. It is evident from the above diagram that only 19% of the total population in the block is engaged in agriculture either as cultivator or as agriculture labour. 1% comprises Household industrial workers and 12% comprises other worker.

In Nandigram II block, 65% of total population is non workers. It is evident from the above diagram that 24% of the total population in the block is engaged in agriculture either as cultivator or as agriculture labour. 1% comprises Household industrial workers and 10% comprises other worker.

Total cultivable area in Nandigram I and Nandigram II block is 13652 ha and 9046 ha respectively. Irrigation in the blocks is achieved by surface and ground water sources. Total CCA or Culturable Command Area created in these blocks is 5718 and 1302 ha. In Nandigram I block ground water irrigation is negligible and less than 1% CCA has been created by ground water and the rest from surface irrigation. On the other hand in Nandigram II block 88% of CCA has been created by ground water irrigation and limited area under surface irrigation networks.

Surface irrigation network comprises tanks, surface flow and lift irrigation. No canal irrigation networks are reported from these blocks. Due to brackish nature of shallow ground water and tidal influences in river channel irrigation is not well developed in these blocks.

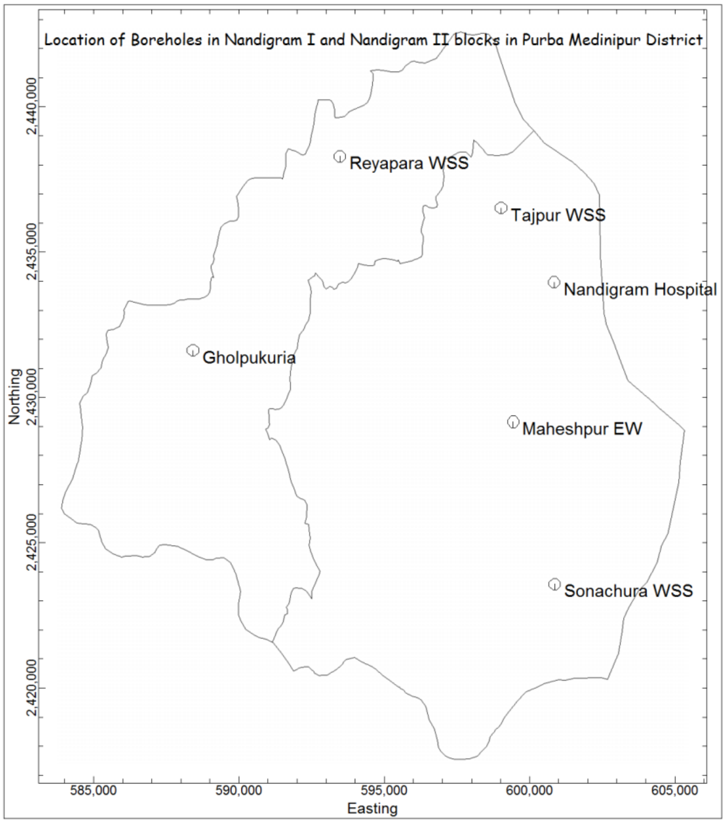
Ground water irrigation is not at all reported from Nandigram I block whereas in Nandigram II block 1150 ha CCA has been produced from ground water irrigation through shallow, medium and deep tube wells.

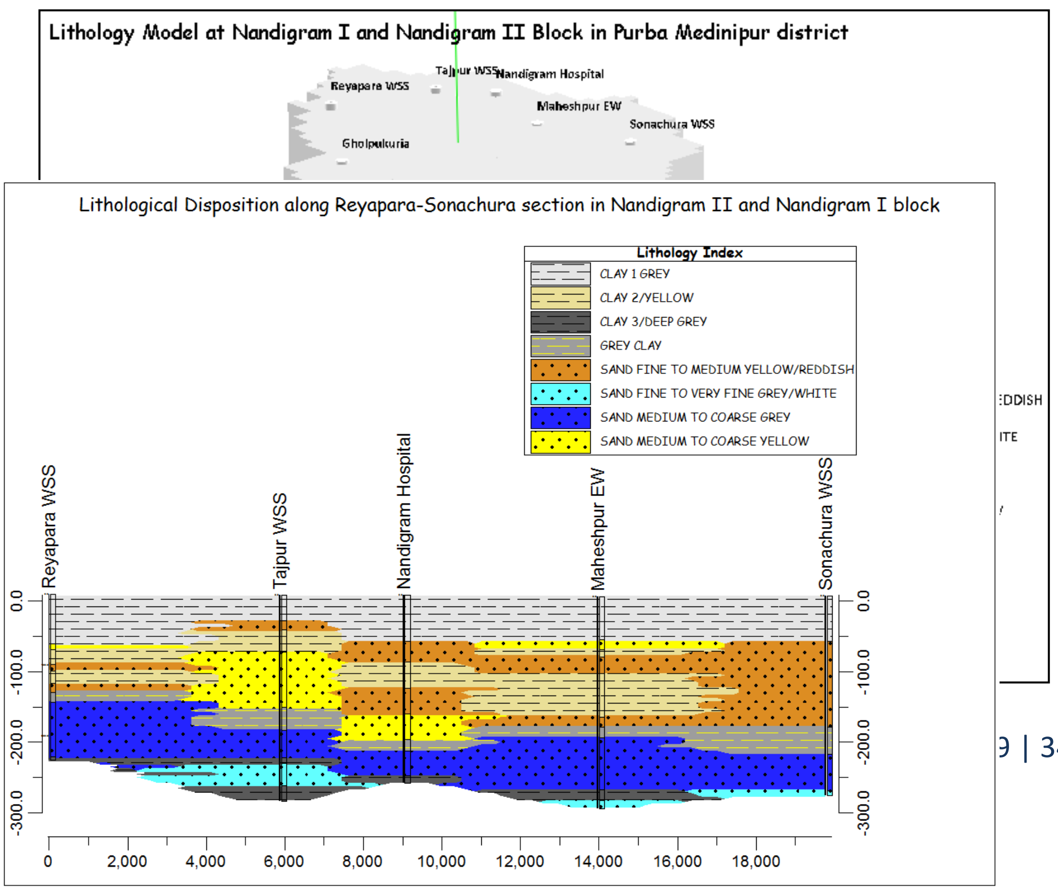
Table 16.6 CCA Created by Different Sources (2013-14)

Block Name	Shallow Tubewell		Medium Tubewell		Deep Tubewell		Surface Flow		Surface Lift		CCA(ha.) Total CCA(ha.)		
	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	Ground Water	Surface Water	Total
Nandigram I	3.00	3.00	2.00	42.56	0.00	0.00	79.00	156.01	392.00	5515.80	46.46	5671.81	5718.27
Nandigram II	27.00	163.15	68.00	975.86	0.00	0.00	0.00	0.00	43.00	153.30	1149.01	153.30	1302.31

16.5 Geology and Sub-Surface Geology

The blocks are underlain by Quaternary sediments of Holocene and Pleistocene age. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt. Departments, the actual lithology and interpreted aquifer models are prepared, and aquifer systems has been classified.

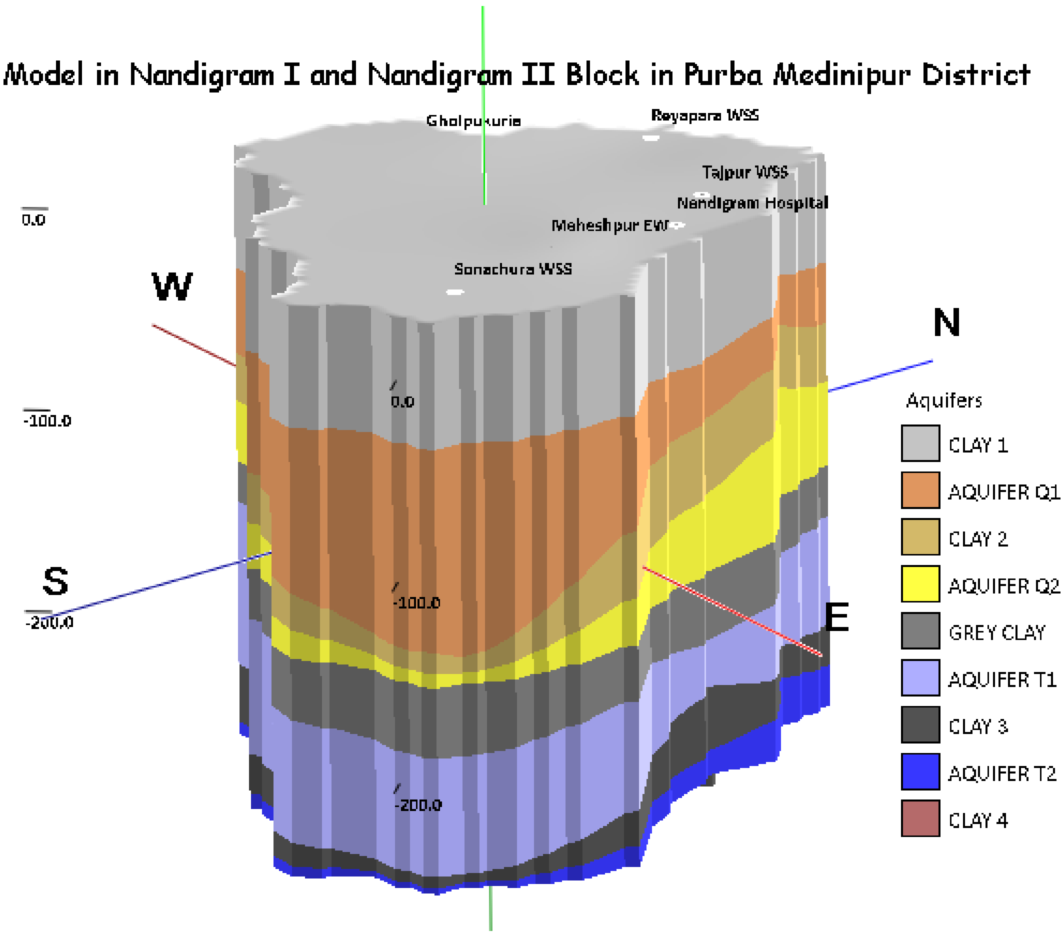

Location of Boreholes in Nandigram I and Nandigram II blocks in Purba Medinipur District
Reyapara WSS
Tajpur WSS
Nandigram Hospital
Gholpukuria
Maheshpur EW
Sonachura WSS
Northing
2,440,000
2,435,000
2,430,000
2,425,000
2,420,000
Easting
585,000
590,000
595,000
600,000
605,000


Lithology Model at Nandigram I and Nandigram II Block in Purba Medinipur district
Tajpur WSS
Nandigram Hospital
Reyapara WSS
Maheshpur EW
Sonachura WSS
Gholpukuria
Lithological Disposition along Reyapara-Sonachura section in Nandigram II and Nandigram I block
Lithology Index
CLAY 1 GREY
CLAY 2/YELLOW
CLAY 3/DEEP GREY
GREY CLAY
SAND FINE TO MEDIUM YELLOW/REDDISH
SAND FINE TO VERY FINE GREY/WHITE
SAND MEDIUM TO COARSE GREY
SAND MEDIUM TO COARSE YELLOW
Reyapara WSS
Tajpur WSS
Nandigram Hospital
Maheshpur EW
Sonachura WSS
0.0
-100.0
-200.0
-300.0
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000

The area of both the blocks is overlain by thick consistent surface clay (40-50 m thick). The surface clay is mostly gray in colour representing younger alluvium. The thick surface clay is followed by yellow to brown sands fine to medium grained of Quaternary age. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and tertiary boundary is marked by occurrences of thick gray clay. Tertiary gray clay is thick and consistent and is found to occur at an average depth of 160 mbgl. The depth of occurrences of Tertiary clay varies in the blocks. The average thickness of the Tertiary clay is 25-30 m. Below the gray tertiary clay fine to medium grained greyish white sands of considerable thickness alternating with intervening clay constitute the Tertiary sedimentation within the explored depth.

16.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:

Aquifer Model in Nandigram I and Nandigram II Block in Purba Medinipur District



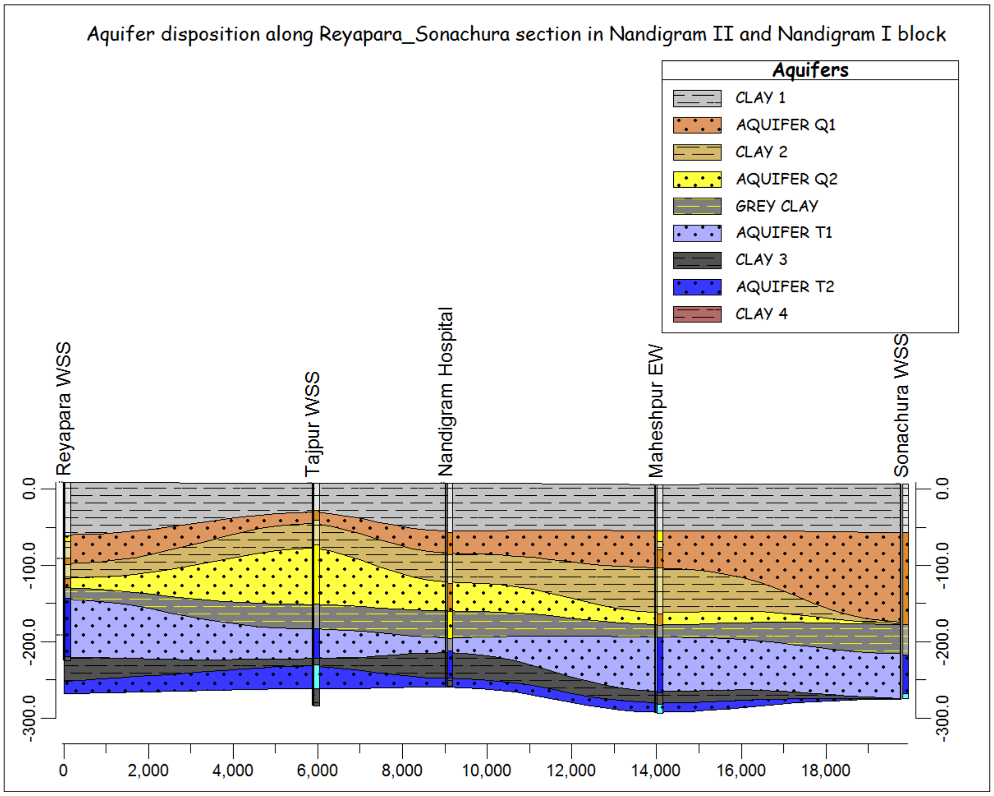


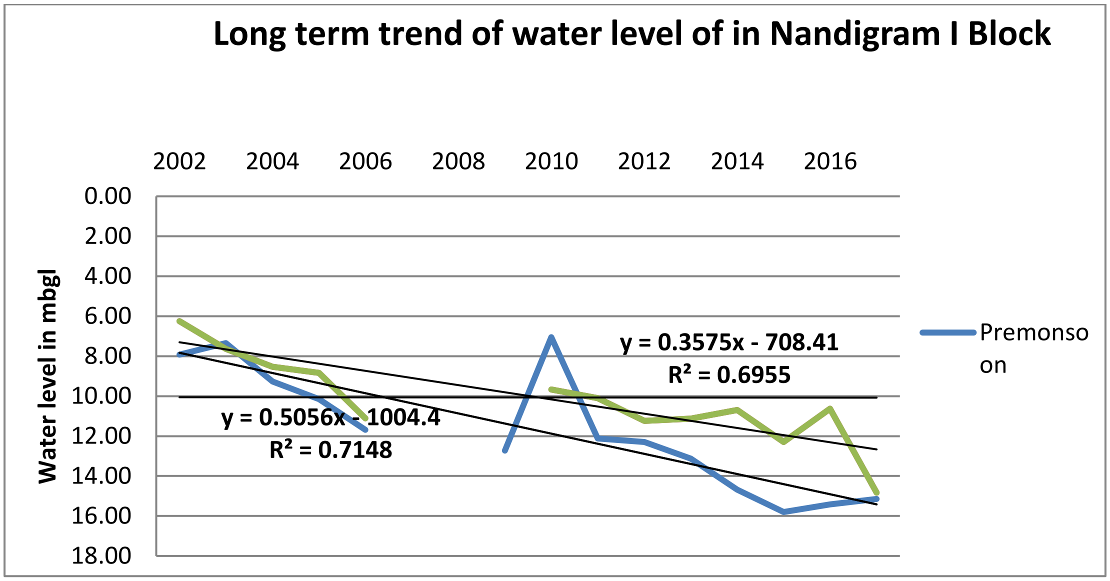
Table 16.7 Disposition of Aquifers and Q/T Boundary in Nandigram I and Nandigram II Blocks

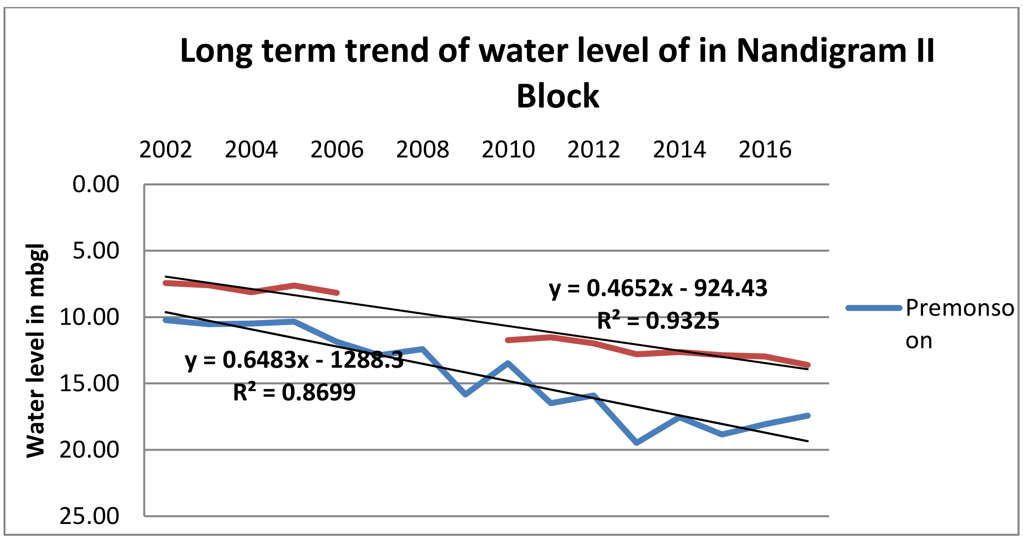
Block	Quaternary Aquifers						Q/T Boundary			Tertiary Aquifers					
	Q1			Q2						T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Nandigram I & II	53.00	101.20	48.20	117.00	158.25	41.25	163.60	190.80	27.20	190.80	249.80	59.00	266.00	279.25	17.67

The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. The cumulative thickness of Quaternary aquifer is 90 m and Tertiary aquifer in the area is about 70-80 m. Both these aquifers are thick, consistent and potential. The thickness of the individual aquifers varies from place to place; the Q1 is thickest around Sonachura area in Nadigram I block (100m) and represents the Quaternary sands in the area. The Q/T boundary is very distinctive and is marked by thick persistent gray clay throughout the area. The two Tertiary aquifers T1 and T2 are separated by steel dark gray clay.

Ground water condition: Groundwater, in both quaternary and tertiary aquifer system is under semi-confined to con- fined condition. Pre and post monsoon water level have been monitored from number of observation wells (180-280 m depth) in Tertiary aquifer systems. Due to the paucity of the working tube wells in the quaternary aquifer, the monitoring data from the quaternary aquifer was limited. The piezometric water level data of CGWB and SWID has been compiled and long term water level 2002-2017 has been analysed from SWID data for Tertiary aquifer only. It is observed that Tertiary registers a long term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow from NW-SE. However, the ground water flow pattern in the area is influenced by the local development status in the surrounding area. The piezometric surface varies between 10.6 m below msl to 14 m below msl.

Block	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m below msl)
Nandigram I	6	15.6-22	11.6	50 cm fall	35 cm fall	-10.6
Nandigram II	6	17.5-20	12.6-15	64 cm fall	46 cm fall	-12.2 to -14.00





Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is high about 60-120 m^3/hr with moderate drawdown of below 6 m. The specific capacity ranges between 20-35 m^3/hr/m drawdown.

***Aquifer* Wise Ground Water Resource Availability**

The aquifer which is proficiently developed in these blocks is the Tertiary aquifer. The Tertiary aquiferis in semi-confined to confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl, therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area.

Table 16.8 Details of resource available in Tertiary aquifer (in MCM) in Blocks

Resource Availability	Nandigram I	Nandigram II
Resource by Storage	21.5153	12.3458

Table 16.9 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in (m^2/day)	Annual Flow in MCM
Sutahata	14.33	0.000300	2000.00	3.14
Haldia	20.67	0.000300	2000.00	4.53

16.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from Tertiary aquifers the following chemical parameters are detected in Nandigram I and Nandigram II block

Table 16.10 Results of Chemical analysis

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO_3	HCO_3	TA as CaCO3	Cl	SO_4	NO_3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO_4	Fe
1	Sonachura PH 2	Nandigram 1	Tertiary	7.86	966	bdl	256	420.9	78	20	1.1	48	7	150	156	16	3.6	bdl
2	Gholpukur	Nandigram 2	Tertiary	7.95	934	bdl	146	317.2	107	32	21	52	9	165	131	12	1.9	0.53
3	Maheshpur	Nandigram I	Tertiary	7.53	1110	710.4	0	292.8	240	198.5	3.4	0.88	40	48.5	300	120.5	9.8	

The water from Tertiary is fresh. The water is mostly sodium chloride and sodium bi-carbonate water.

16.8 Ground Water Resource Enhancement and Management Plan:

16.8.1 Ground Water Management Plan for drinking purposes

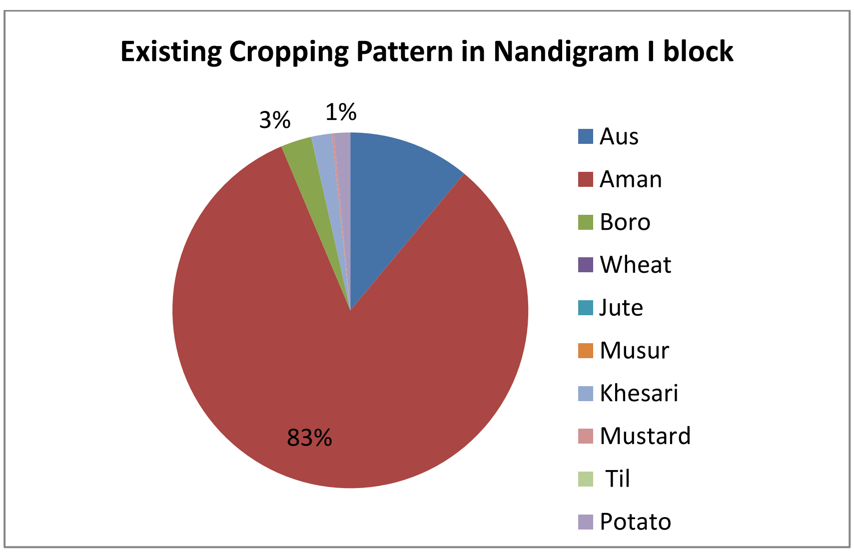
PHED, Govt. of West Bengal is entrusted for supply of drinking water in these blocks. Besides spot sources of hand pumps, mark II tube wells, PHED has so far commissioned 5 no ground water-based water supply schemes in Nandigram I block and 1 no ground water based schemes in Nandigram II block. Besides above 2 ongoing schemes are under commissioning in Nandigram II block. Few of these schemes have been subsequently augmented. It has been assessed that tentative covered population through these schemes is 63177 in Nandigram I and 75899 in Nandigram II block. Therefore, 144658 remaining population in Nandigram I block need to be brought under water supply schemes for which about 2.11 MCM water is required. On the other hand, in Nandigram II block 47320 remaining population need to be brought under water supply schemes for which about 0.70 MCM water is required. The Tertiary aquifers in these blocks are meant to supply drinking water in these blocks. Thus, 10 drinking water tube wells in Nandigram I block and 3 tube wells in Nandigram II block may further be constructed in phases to meet the demand from ground water resources. Further development of this aquifer will definitely affect the ground water regime in the area. It is observed that the probable decline of piezometric surface in Tertiary aquifer in Nandigram I area would be 17 m whereas in Nandigram II would be 9.60 m. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation should always be compensated by construction of suitably design artificial recharge structures in respective aquifers.

Table 16.11 Development Proposal of Tertiary Aquifers with implication on Piezometric Surfaces of Each Aquifer

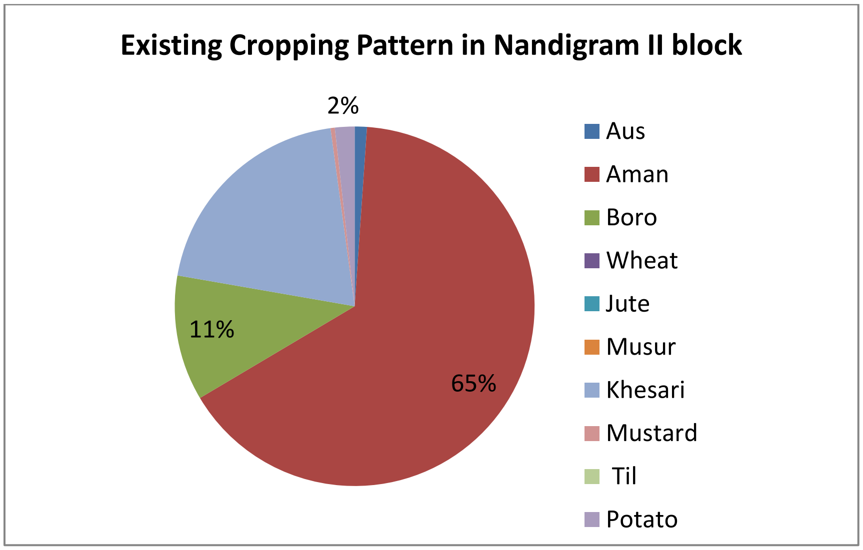
Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncovered population @40lpcd in MCM	Annual resource proposed to be utilized from Quaternary Aquifer in MCM	Annual resource proposed to be utilized from Tertiary Aquifer in MCM	Total annual unit draft of one TW in MCM (considering average discharge of Quaternary and 8 hrs/day running)	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary and 8 hrs/day running)	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquifer	Decline of piezometric surface in Quaternary Aquifer (in m)	Decline of piezometric surface in Tertiary aquifer(in m)
Nandigram I	181.84	2.1120	0.0000	2.1120		0.2044	0	10	NA	17
Nandigram II	105.74	0.6909	0.0000	0.6909		0.1752	0	3	NA	9.60

16.8.2 Management Plan for irrigation:

Present cropping pattern in Nandigram I block: The crop grown statistics in Nandigram I Block shows rain fed Aman paddy constitute the 83% of the total crop grown, Aus paddy includes 11%, bore is less and constitute 3%. The other crops are limited Khesari, Mustard and Potato. Brackish to saline ground water and tidal influence in river or khal water impedes irrigation development in the block.



Present cropping pattern in Nandigram II block: The crop grown statistics in Nandigram II Block shows that Aman constitute 65 % total crops followed by Khesari, Boro, Potato, Aus and limited Mustard. Brackish to saline ground water and tidal influence in river or khal water impedes irrigation development in the block



The cultivable area of the Nandigram I block is 13652 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA created in the block is 5718 ha. Further, 7933.73 ha area is to be brought under irrigation coverage in the blocks. The irrigation tube wells are not very common in the block.

The cultivable area of the Nandigram II block is 9046 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA created in the block is 1302 ha. Further, 7743.69 ha area is to be brought under irrigation coverage in the blocks. The irrigation tube wells are not very common in the block.

The Quaternary aquifer is reported with brackish to saline water. Tertiary aquifers are under semi confined to confined condition and witnesses steady decline of water level, therefore, further development of irrigation tube wells is not recommended. In contrary to these the trivial modification of cropping pattern may bring more area under irrigation in the blocks, therefore increases the intensity of cropping. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 97.20 ha m of water in Nandigram I block and

176.40 ham of water in Nandigram II block. This volume of water may be used to mustard, pulses potato etc. as per the prevailing cropping pattern in the block. Thus, 161.76 ha in Nandigram I block and 293.56 ha in Nandigram II block effective increase in irrigation area may be created by change in cropping pattern. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability.

Table 16.12 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation				Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction(ha)	Volume of Irrgation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor:30 cm)	Potato (Delta factor:60 cm)	Total additional area created in ha	Effective Increase in area(ha)
Nandigram-I	810	1.2	729	97.20		80.92	107.89	53.95	242.76	161.76
Nandigram-II	1470	1.2	1323	176.40		146.85	195.80	97.90	440.56	293.56

16.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non-committed surface runoff produced in Nandigram I block is 27.9095 MCM and runoff produced in Nandigram II block is 16.2294 MCM. The non-committed flow is proposed to be utilized to fill the depleted space in Tertiary aquifers in the blocks. As per the available storage space 1.0946 MCM water is required to fill the available storage space in Tertiary aquifer in Nandigram I and 0.7276 MCM water is required to fill the space in Tertiary aquifers in Nandigram II. Therefore, 82 injection wells with roof top rain water harvesting structures is recommended in Tertiary aquifer in Nandigram I and 55 injection well in Nandigram II. The successful implementation of recharge structures may raise the piezometric surface in the above area to the extent of 8.85 m to 10.12 m. Further, in case of construction of more tube wells in Tertiary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated.

The remaining non committed runoff, 26.8149 MCM in NandigramI block is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 536 storage / irrigation tanks have been proposed. Thus, in Nandigram II block the remaining non committed runoff of 15.5018 MCM of water may be utilized for generation of irrigation potential by construction of 310 storage tanks. These tanks can generate additional irrigation potential of 4022 ha in Nandigram I block and 2325 ha in Nandigram II block considering average delta factor of 50 cm for pulses, rabi crop, vegetables, etc. Therefore, by change in cropping pattern and utilizing the non-committed runoff through tank irrigation total 4184 ha additional irrigation potential can be created in Nandigram I which accounts for 53% coverage in the remaining area where irrigation facilities were to be extended. Similarly, in Nandigram II block 2619 ha additional irrigation potential may be created which accounts for 34% coverage wrt the remaining area. The roof top rain water harvesting structures with suitably design injection wells may be proposed to construct in the urban area/census towns in primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with 1-2 irrigation tanks for harvesting of surface runoff at suitable locations and for subsequent irrigation uses.

Summary of Management Plan:

- *Drinking water tube wells have been recommended in Tertiary aquifer to meet the uncovered demand from ground water sources. Thus, 10 tube wells in Nandigram I block and 3 tube wells in Nandigram II block are recommended.*
- *The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of 82 injection wells in Tertiary aquifer in Nandigram I block and 55 injection wells in Nandigram II*

block. The construction of injection wells should be accompanied with suitable designed roof top rain water harvesting structures and may be constructed in phases as per the situation.

- *Further construction of irrigation tube wells is restricted. The boro area may be reduced by 10% of existing area, and the surplus water may be used to irrigate pulses, etc. Thus few additional irrigation potential can be generated.The non committed runoff may beharvested through construction of irrigation cum storage tanks.*

17.0 MANAGEMENT PLAN OF PANSKURA BLOCK

17.1 Location, Demography and Rainfall

Panskura is located at 22.397°N latitude and 87.741°E longitude. Bounded in the east and south by Kolaghat and Moyna, Tamluk block of Purba Medinipur district respectively, in the west and north by Paschim Medinipur district

- Subdivision: Tamluk
- Sub basin: Rupnarayan
- Geographical Area:
- Panskura Block: 227.14 sq km.
- Panskura Municipality: 19.94 sq.km

Population (2011 Census)

Table 17.1 Total population of the Block

Total Population	Rural Population	Urban Population
3,41,235	2,83,303	57,932

The block comprises 14 Gram Panchayets, 232 villages, 296 habitations and 66284 household

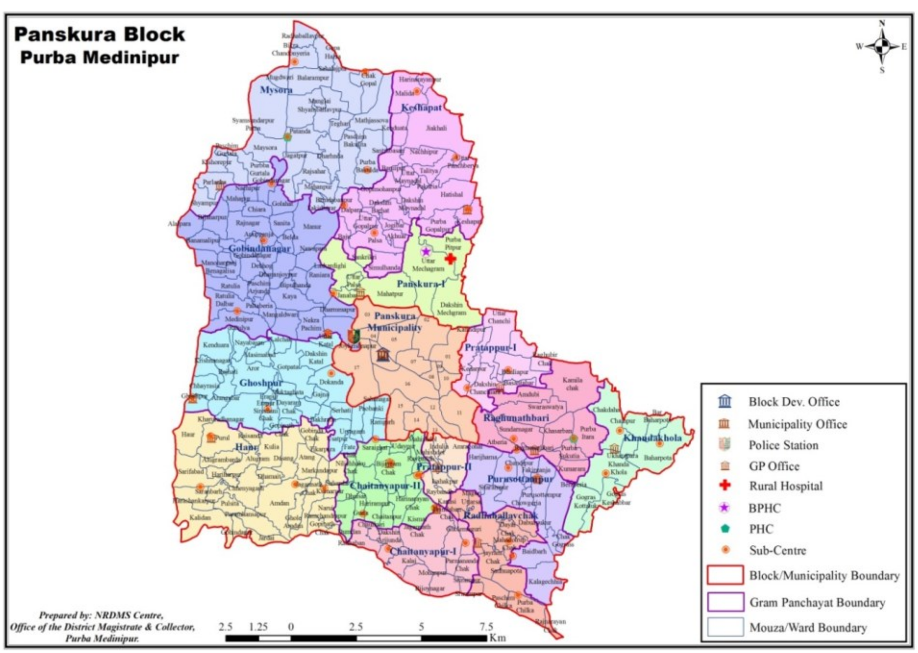


Figure 17.1 Gram-Panchayet and Mouza Map of Panskura Block

Table 17.2 Basic Demographic Detail of Panskura Block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	HouseHolds	Population
1	Chaitanyapur-i	10	10	2777	11779
2	Chaitanyapur-ii	13	20	3595	17156
3	Ghoshpur	27	28	5090	22168
4	Gobindanagar	32	32	6861	31162
5	Haur G.p	29	29	6562	26971
6	Keshapat	23	63	6301	29009
7	Khandakhola	8	8	4070	18382
8	Mysora	27	37	6848	31718
9	Panskura-i	9	9	3934	17694
10	Pratappur-i	13	13	5425	24666
11	Pratappur-ii	6	7	1523	7604
12	Purusotttampur	13	15	3843	17181
13	Radhballavchak	12	14	5007	23263
14	Raghunathbari	10	11	4448	20170
	Total	232	296	66284	298923

Source: PHED, Govt of WB, Website

- **Normal Annual Rainfall** in the district: 1663.40 mm

Table 17.3 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall
Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

17.2 Physiographic and Drainage:

The block is a part of lower Gangetic plain and almost entire blocks is in Rupnarayan sub-basin. The river Rupnarayan which is flowing in SE direction along the eastern boundary of the Kolaghat block controls the drainage network of the block. The tributaries of Rupnarayan also constitute the drainage volume of the block. Average elevation varies from 2-5 m amsl and highest being 9 m amsl. The dominant soil type of the block is very poorly drained impermeable clayey soil; however, along the central parts of the block imperfectly drain soils are encountered.

The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

17.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 17.4 Details of Land use pattern of block (area in ha)

Name of the block	Reporting area	Forest area	Area under non-agriculture wastes	Barren and un-culturable lands	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Net area sown
Panskura	24679	0	7201			95			407	16976

17.4 Agriculture and Irrigation:

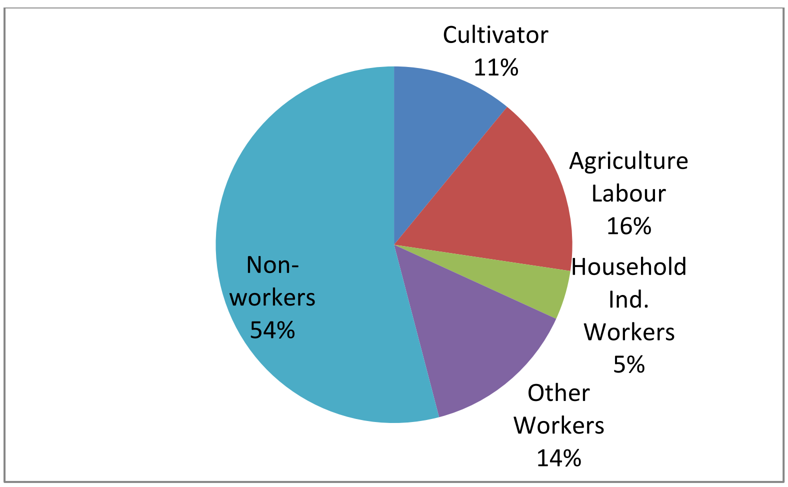


Table 17.5 Distribution of persons engaged in agriculture and other workers/non workers in the Block

In Panskura block, 54% of total population is non workers. It is evident from the above diagram that 27% of the total workers in the block are engaged in agriculture either as cultivator or as agriculture labour. 5% comprises Household industrial workers and 14% comprises other worker.

Irrigation in the block is achieved by surface and ground water sources. The Culturable Command area (CCA) created by ground water resources constitute 90% of the total CCA in the block. Surface water irrigation coverage is less than 10% in the block. About 13234 ha area has been brought under CCA by surface and ground Water irrigation network**.**

Surface irrigation network comprises canals, tanks, surface flow and lift irrigation. As per the District Statistical Hand book, 2014, about 777 ha area has been covered by canal irrigation. Surface flow, lift and tank irrigation comprises other mode of surface irrigation networks in the block.

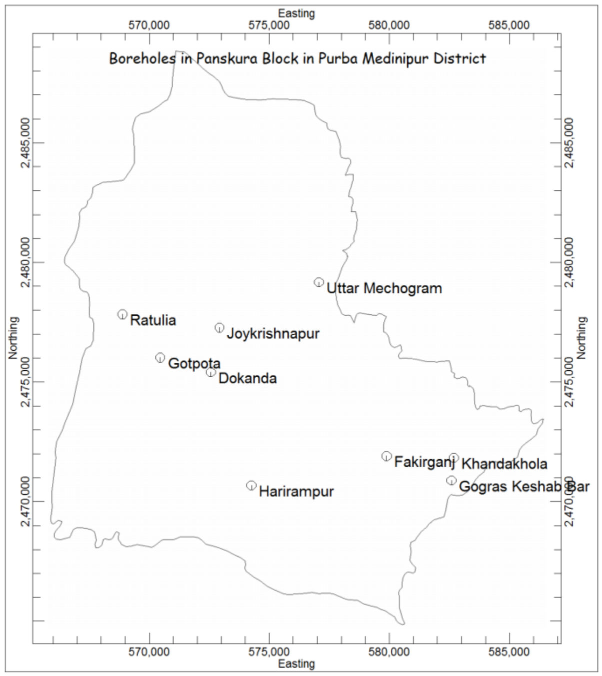
Ground water irrigation is mainly through shallow tube wells and limited numbers of deep tube wells. The CCA created by about 600 shallow tube wells is 2350 ha, 477 medium deep tube wells 3418 ha and 240 deep tube well 6189 ha. The command area of STW and DTW is 10 ha and 40 ha respectively.

Table 17.6 CCA Created by Different Sources in the block (2013-14)

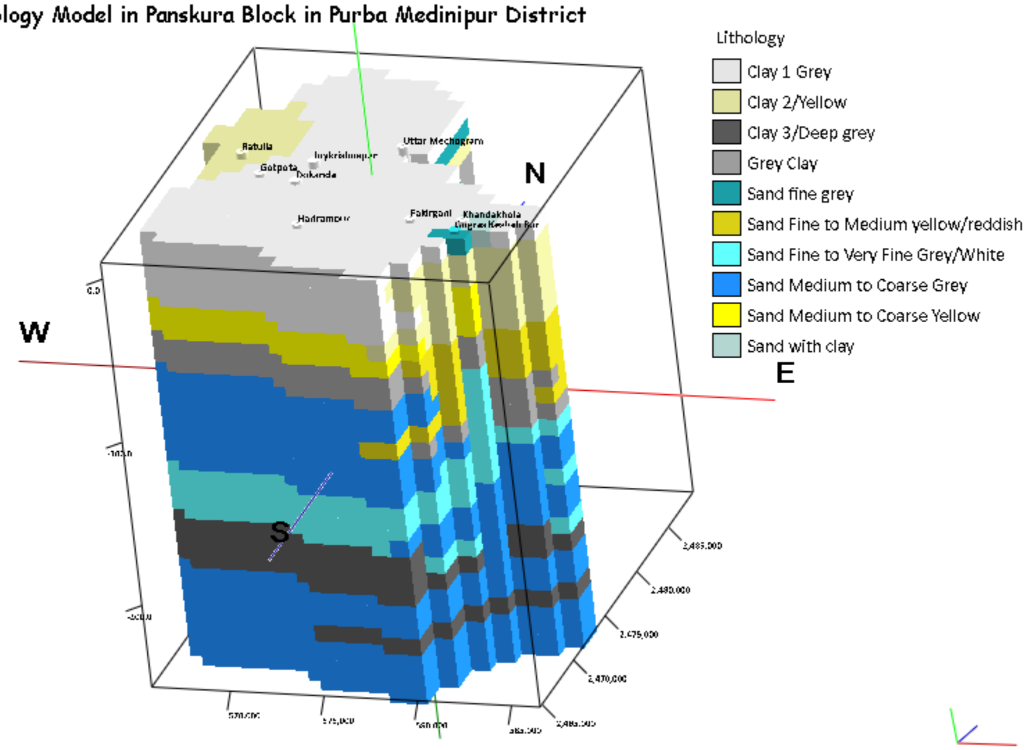
Block Name	Dugwell		Sallow Tubewell		Medium Tubewell		Deep Tubewell		Surface Flow		Sarface Lift		CCA(ha.)		Total CCA(ha.)
	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	Ground Water	Surface Water	
Panskura	6.00	32.81	546.00	2349.77	477.00	3418.70	240.00	6188.69	10.00	208.05	89.00	1035.90	11989.97	1243.95	13233.92

17.5 Geology and Sub-Surface Geology

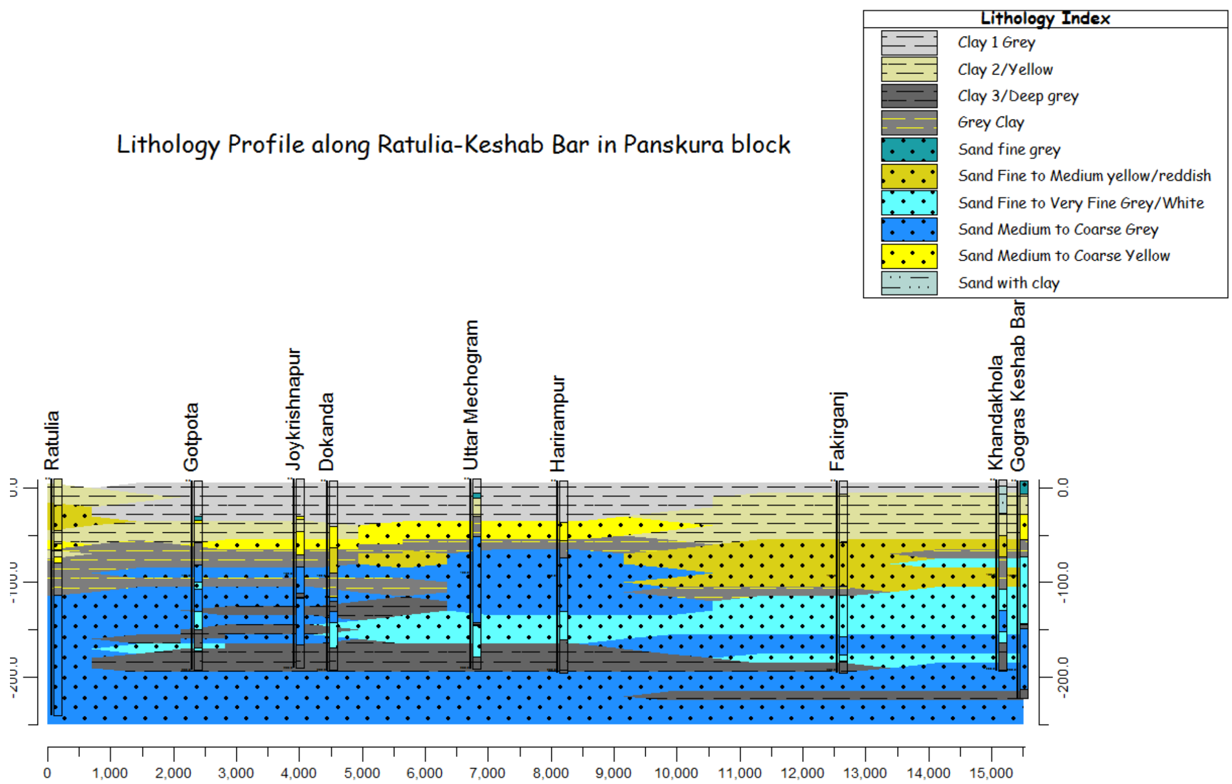
The block is covered by Holocene sediments. The newer alluvium of Holocene age is underlain by Pleistocene Quaternary sediments. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt. Departments, the actual lithology and interpreted aquifer models are prepared, and aquifer systems have been classified.



Lithology Model in Panskura Block in Purba Medinipur District

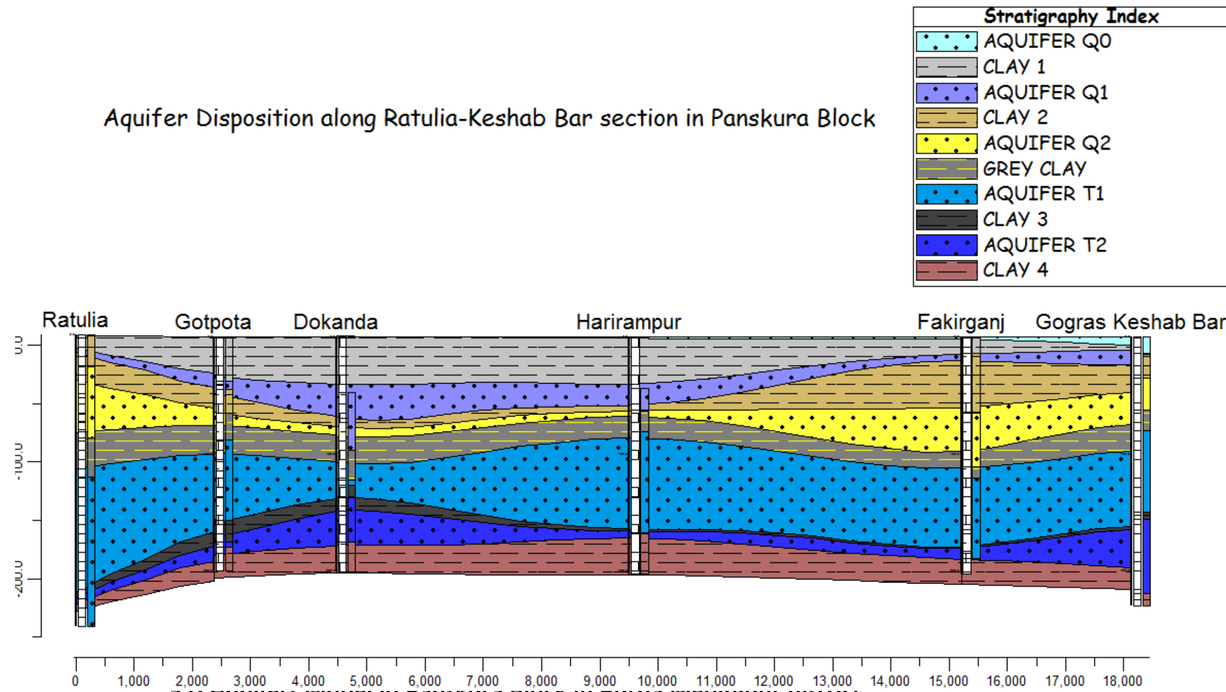


The lithology model reveals that the block is underlain by thick surface clay of 20-25 m thick. The surface clay is mostly gray in colour representing younger alluvium, however in few patches around Ratulia village in the western parts of the block yellow clay of older alluvium origin is found at the surface. The lithology is represented by alternate sequence of sands of fine to medium and coarse and clay. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and tertiary boundary is marked by occurrences of thick gray clay. Tertiary gray clay is thick and consistent and is found to occur at an average depth of 70-75 mbgl in Panskura block. The thickness of the Tertiary clay is 20-25 m.



17.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:

Aquifer Disposition along Ratulia-Keshab Bar section in Panskura Block



3 D Aquifers Model in Panskura Block in Purba Medinipur district

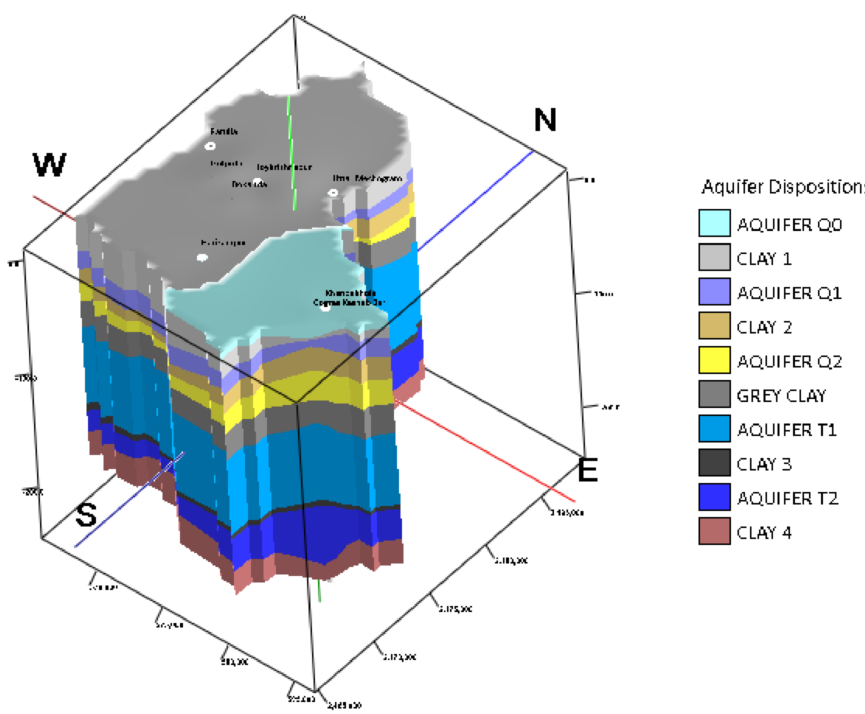


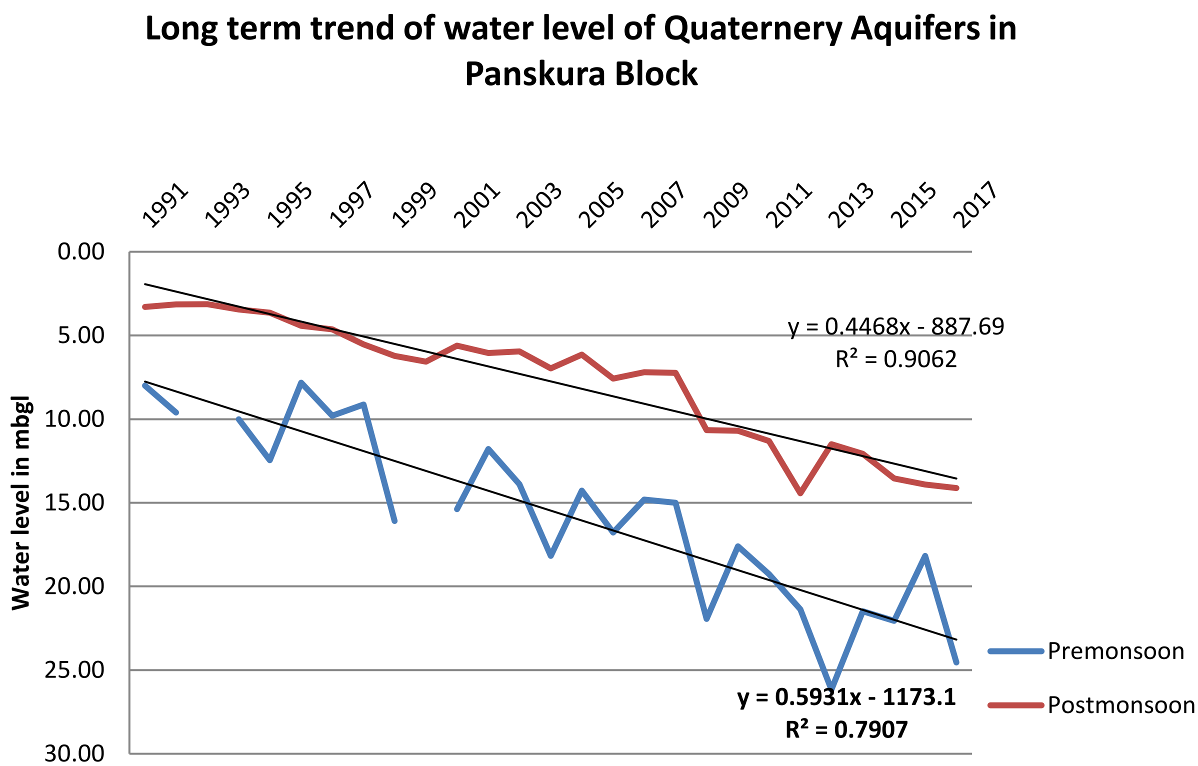
Table 17.7 Disposition of Aquifers and Q/T Boundary In Panskura Block

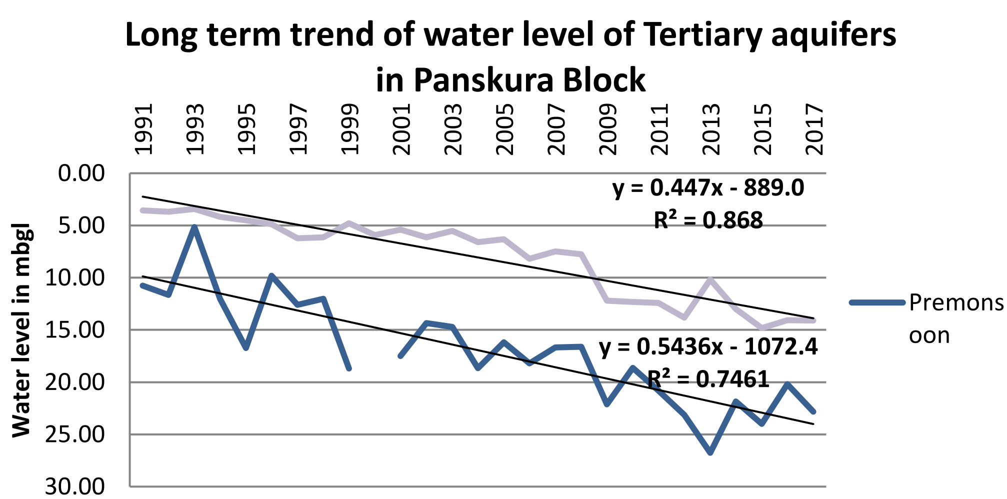
Block	Quaternary Aquifers						Q/T Boundary			Tertiary Aquifers					
	Q1			Q2						T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Panskura	26.75	41.25	19.17	56.56	75.78	34.40	76.11	97.78	21.67	97.78	164.67	66.89	169.67	190.56	37.40

The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. The cumulative thickness of Tertiary aquifer in the area is more (104 m) than that of quaternary aquifers (53.57 m). The Tertiary aquifers are very thick in the block. The stratigraphic correlation reveals undulatory nature of deposition surface.

Ground Water Condition : Ground water in both the aquifer system is under confined condition. Pre and post monsoon water level have been monitored from number of observation wells of each aquifer systems. The data of CGWB and SWID has been compiled and long term water level 1991-2017 has been analyses from SWID data. It is observed that the both aquifer system registers a long term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow from NW-SE and NE-SW from 10 m below sea level to 18 m below sea level in Tertiary and 12 m to 18 m below sea level in Quaternary aquifers. The ground water flow is influenced by local ground water development in the block.

Aquifer system	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m below msl)
Quaternary	5	18.9-24.8	10.8-15.85	59 cm fall	44 cm fall	-12 to -18
Tertiary	17	19.5-26.5	11.00-15.00	54 cm fall	44 cm fall	-10 to-18 m





Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is about 75-120 m^3/hr with moderate drawdown of 4-5 m. The specific capacity ranges between 5-35 m^3/hr/m drawdown. Irrigation shallow tube wells in the quaternary aquifer is reported to yield at 30-50 m^3/hr. The results of pumping test of exploratory wells of CGWB in Gumai and Ratulia reveals the Transmissivity of the Tertiary aquifer 2659 m^2/day and 983 m^2/day respectively. The storativity value is around $4X10^{-4}$ -$5.465X10^{-4}$.

***Aquifer* Wise Ground Water Resource Availability**

The entire block is under confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl , therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area.

Table 17.8 Details of aquifer wise resource availability (in MCM) in Block

Resource Availability	Quaternary Aquifer	Tertiary Aquifer
Resource by Storage	2.7897	6.0646

Table 17.9 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in (m^2/day)	Annual Flow in MCM
Panskura	20.67	0.000386	2000.00	5.83

17.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from Tertiary aquifers the following chemical parameters are detected in Panskura block.

Table 17.10 Results of Chemical analysis of Tertiary aquifer in Panskura

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO_3	HCO_3	TA as CaCO3	Cl	SO_4	NO_3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO_4	Fe
1	Gobindanagar	Panskura	Tertiary	7.94	536	bdl	232	190	36	5	1	40	1	105	60	7.8	3.1	0.51
2	Dokanda	Panskura	Tertiary	8.08	1874	bdl	616	505	277	4.6	12	18	2	190	281	81.9	1.8	0
3	Ratulia dolbar	Panskura	Tertiary	8.06	522	bdl	232	190	25	21	16	28	16	250	3	1.95	0	6.72
4	Gotpota	Panskura	Tertiary	8.14	495	bdl	244	200	18	5	7	14	4	165	28	23.4	1.8	1.85
5	Gopimohanpur	Panskura	Tertiary	7.23	817	bdl	384	315	46	13	5.2	26	7	120	110	31.2	2.5	1.13
6	Deulbrah	Panskura	Tertiary	7.79	900	bdl	311	255	121	15	7.1	16	2	155	131	7.8	3.8	7.22
7	Gumai	Panskura	Tertiary	7.61	828	bdl	190	232	25	20	7.5	40	4	115	138	11.7	5.9	bdl
8	Amdan	Panskura	Tertiary	7.94	530	bdl	355	433	18	23	8.1	38	4	110	69	3.9	4.7	bdl
9	Pitpur	Panskura	Tertiary	8.09	452	bdl	210	256	25	27	15	12	15	90	50.6	19.5	5.8	0.54

The water from Tertiary is fresh except one or two samples. The concentration of Fe in ground water much higher than the permissible limit has been detected around Ratulia, Deulbar, Gotpota etc.

17.8 Ground Water Resource Enhancement and Management Plan:

17.8.1 Ground Water Management Plan for drinking purposes

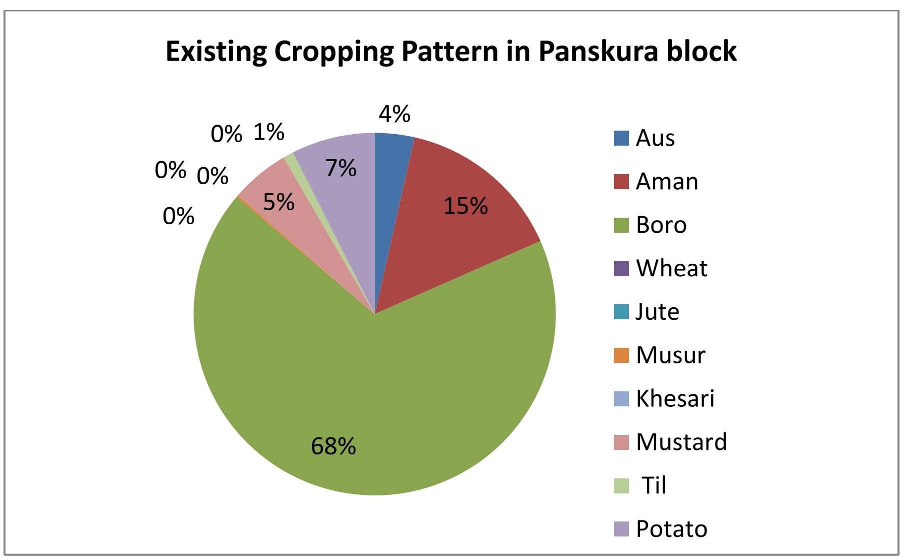
PHED, Govt. of West Bengal is entrusted for supply of drinking water in the block. Besides spot sources of hand pumps, mark II tube wells PHED has so far commissioned 4 no ground water based water supply schemes and 3 more ground water based schemes are under commissioning in the block. It has been assessed that total covered population through these schemes is about 73547. Therefore, 267688 remaining population need to be brought under water supply schemes for which about 3.9082448MCM water is required. Both quaternary and Tertiary aquifers may be developed for supply of drinking water to the uncovered population and following the prevailing practices in the area 60% of the proposed demands may be met from Tertiary and rest 40% from Quaternary. Thus, 11 drinking water tube wells in Quaternary and 8 drinking water tube wells in Tertiary may further be constructed in phases to meet the demand from ground water resources. Therefore, further development of these aquifers will definitely affect the ground water regime in the area. It is observed that the probable decline of piezometric surface in Aquifer I is 17.77 m and the probable decline piezometric surface in Aquifer II is 26.66 m. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation in these aquifers should always be compensated by construction of suitably design artificial recharge structures in respective aquifers.

Table 17.11 Development Proposal of Quaternary and Tertiary Aquifers with implication on Piezometric Surfaces of Each Aquifers

Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncovered population @40lpcd in MCM	Annual resource proposed to be utilized from Quaternary Aquifer in MCM	Annual resource proposed to be utilized from Tertiary Aquifer in MCM	Total annual unit draft of one TW in MCM (considering average discharge of Quaternary and 8 hrs/day running)	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary and 8 hrs/day running)	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquifer	Decline of piezometric surface in Quaternary Aquifer (in m)	Decline of piezometric surface in Tertiary aquifer(in m)
Panskura	227.14	3.9082448	1.56329792	2.34494688	0.1314	0.2628	11	8	17.77	26.66

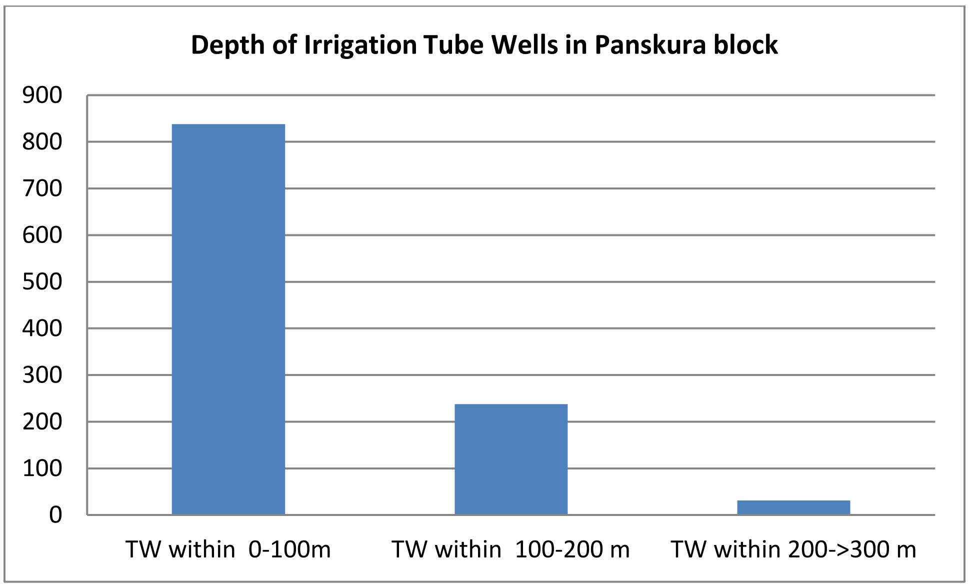
17.8.2 Management Plan for irrigation:

Present cropping pattern in the block: The major crop in the block is boro paddy which accounts for 68% of total crops in the block, other includes rain fed aman paddy , wheat , jute, mustard , potato with limited area and yield.



The cultivable area of the block is 17478 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA in the block is 13233.92ha. Further, 4244.08 ha area is to be brought under irrigation coverage in the blocks.

More than 76% of irrigation tube wells lie within the depth range of 0-100 m and 21% lies within 100-200 m.



Since, both Quaternary and Tertiary aquifers in the block is under semi confined to confined condition and witnesses steady decline of water level therefore, further development of irrigation tube wells is not recommended. In contrary to these the trivial modification of cropping pattern may bring more area under irrigation in the blocks, therefore increases the intensity of cropping. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 1431.60 ha m of water. This volume of water is used to cultivate oilseeds (sunflower/ mustard), pulses and floriculture crops like marigold, bell, tube rose etc. **Thus, 3707 ha effective increase in irrigation area** may be created by change in cropping pattern. Owing to the nature of soil types of wheat is not recommended. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability.

Table 17.12 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation				Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction(ha)	Volume of Irrgation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor: 30 cm)	Floriculture (Bell, Merrigold, tuberose) (Delta factor:22.5 cm)	Total additional area created in ha	Effective Increase in area(ha)
Panskura-I	11926	1.2	10733	1431.60		1191.81	1589.08	2118.77	4899.65	3707.05

17.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non committed surface runoff produced in the block is 34.8623 MCM. The non-committed flow is proposed to be utilized to recharge both Quaternary and Tertiary aquifers in the block. As per the available storage space 0.8148 MCM and 0.8604 MCM water is required to fill the available storage space in quaternary and tertiary aquifers respectively in the block. Therefore, 65 and 61 injections well with roof top rain water harvesting structures is recommended in the rural area of the blocks in tertiary and quaternary aquifers respectively. The successful implementation of recharge structures may raise the piezometric surface about 10 m. In addition to above, with the available non committed runoff 6 no RTRWHS in Tertiary and 5 nos of RTRWHS in

Quaternary aquifer are recommended in Panskura Municipal area. Further, in case of construction of more tube wells in Tertiary and Quaternary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated. I

The remaining non committed runoff, 33.1872 MCM is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 664 storage / irrigation tanks have been proposed. These tanks can generate additional irrigation potential of 4978 ha considering average delta factor of 50 cm for rabi crops, vegetable, horticulture/ floriculture crops. Therefore, by change in cropping pattern and utilizing the non committed runoff for tank irrigation total 8685 ha further irrigation potential can be created. Thus, the entire cultivable area in the block may be brought under irrigation. The roof top rain water harvesting structures with suitably design injection wells may be proposed to construct in the Municipality area in primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with 1-2 irrigation tanks for harvesting of surface runoff at suitable locations and for subsequent irrigation uses.

Summary of Management Plan:

- *Drinking water tube wells have been recommended in Tertiary and Quaternary aquifers to meet the uncovered demand from ground water sources. 11 tube wells in Quaternary and 8 tube wells in Tertiary have been proposed.*
- *The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of 65 injection wells in Tertiary and 61 injection wells in Quaternary with roof top harvesting arrangements. In the municipality area 11 more injection wells are recommended to construct.*
- *Further construction of irrigation tube wells is restricted. The boro area may be reduced by 10% of existing area, and the surplus water may be used to irrigate pulses, oilseed and floriculture crops. Thus additional 3707 ha irrigation potential can be generated.*

- *The non committed runoff may be used for irrigation tanks. Considering capacity of one tank as 0.05 MCM, 664 irrigation tanks are proposed, preferably one- two in each habitation in the block. This will generate additional irrigation potential of 4978 ha. Thus, the additional irrigation potential created by change in cropping pattern and by harvesting surface runoff will bring the entire cultivable area in the block under irrigation coverage.*

Table 17.13 Proposed Conservation and Recharge Structures based on the available non committed surface runoff and available storage space

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Vol of water kept for conservation/storage tanks in MCM (3-(4+5))	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks (6/8)	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary (4/9)	No of RTRWH with injection well required for Quaternary (5/9)
1	2	3	4	5	6	7	8	9	10	11
Panskura	227.14	34.86	0.8604	0.8148	33.1872	0.05	664	0.0133072	65	61

- *This will generate additional irrigation potential of 4022 ha and 2325 ha respectively. Thus, the additional irrigation potential created by change in cropping pattern and by* *harvesting surface runoff will bring 53% to 34% of the remaining cultivable area under irrigation coverage in Nandigram I and Nandigram II block respectively.*

Table 17.14 Proposed Conservation and Recharge Structures based on the available non committed surface runoff and available storage space

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Vol of water kept for conservation/storage tanks in MCM (3-(4+5))	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks (6/8)	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary (4/9)	No of RTRWH with injection well required for Quaternary (5/9)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nandigram I	181.84	27.9095	1.0946		26.8149	0.05	536	0.0133072	82	
Nandigram II	105.74	16.2294	0.7276		15.5018	0.05	310	0.0133072	55	

18.0 MANAGEMENT PLAN OF SAHID MATANGINI BLOCK

18.1 Location, Demography and Rainfall

Sahid Matangini block is located at 22.4086°N latitude and 87.9128190°E longitude. The block is bounded in the east and northeast by River Rupnarayan, by Kolaghat block in the north western part and by Tamluk development block in the west and south western part.

- Subdivision: Tamluk
- Sub basin: Rupnarayan
- Geographical Area:
- Sahid Matangini Block: 97.82 sq km.
- Population (2011 Census)

Table 18.1 Total population of the Block

	Rural Population	Urban Population	Total
Block	183987	15223	199210

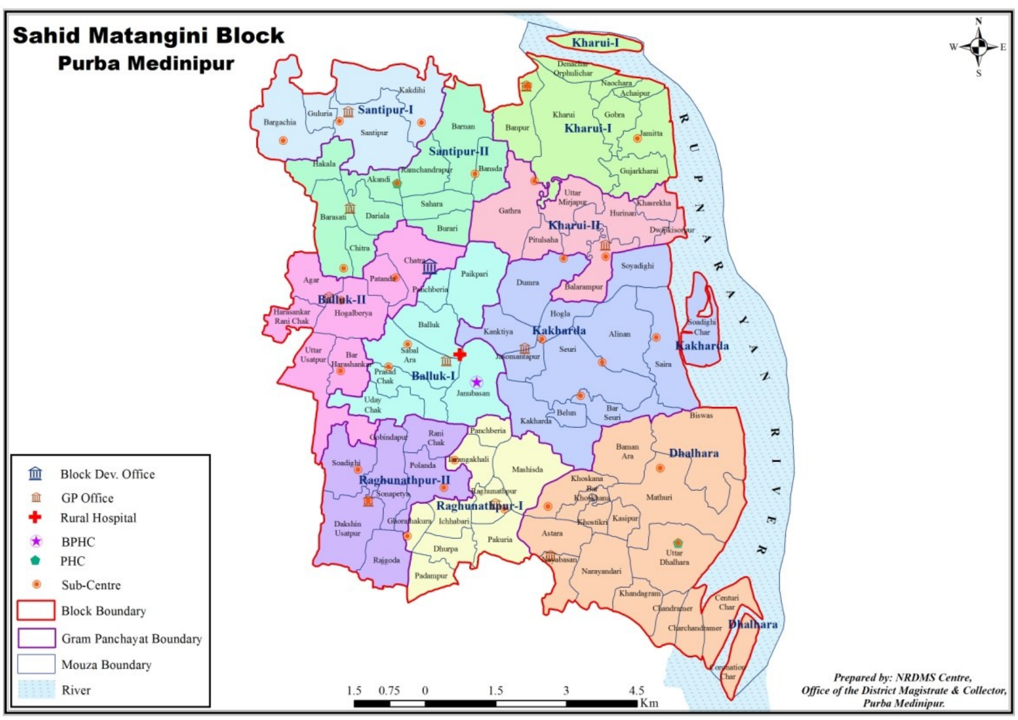


Figure 18.1 Gram-Panchayet and Mouza Map of Sahid Matangini Block

The block comprises 10Gram Panchayets, 84 villages, 261 habitations and 44741 households. Basic Demographic Detail of Sahid Matangini Block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	HouseHolds	Population
1	Balluk-i	7	24	4115	18083
2	Balluk-ii	7	24	3798	16977
3	Dhalhara	13	24	6628	28840
4	Kakharda	12	42	6231	27870
5	Kharui-i	7	13	4433	20319
6	Kharui-ii	8	35	3561	16372
7	Raghunathpur-i	9	23	3761	16516
8	Raghunathpur-ii	7	20	3433	15044
9	Santipur-i	4	17	3874	18604
10	Santipur-ii	10	39	4907	21684
	Total	84	261	44741	200309

Source: PHED, Govt of WB, Website

- **Normal Annual Rainfall** in the district: 1663.40 mm

Table 18.2 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall
Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

18.2 Physiographic and Drainage:

The block is a part of lower Gangetic plain and almost entire blocks is in Rupnarayan sub-basin. The river Rupnarayan which is flowingalong the eastern boundary of theblock controls the drainage network of the block. The tributaries of Rupnarayan also constitute the drainage volume of the block. Average elevation is 3-8 m amsl. The dominant soil type of the block is very poorly drained impermeable clayey soil.

The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

18.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 18.3 Details of Land use pattern of block (area in ha)

Name of the block	Reporting area	Forest area	Area under non-agriculture wastes	Barren and un-culturable lands	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Net area sown
Sahid Matangini	9570	0	2724			94				6752

18.4 Agriculture and Irrigation:

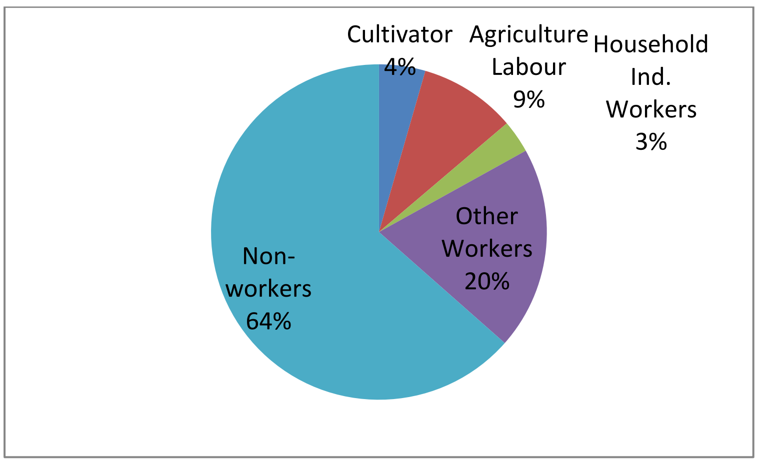


Figure 18.2 Distribution of persons engaged in agriculture and other workers/non workers in the Block

In Sahid Matanginiblock, 64% of total population is non workers. It is evident from the above diagram that only 13% of the total workers in the block are engaged in agriculture either as cultivator or as agriculture labour. 3% comprises Household industrial workers and 20% comprises other worker.

Irrigation in the block is achieved by surface and ground water sources. The Culturable Command area (CCA) created by surface water resources constitute 90% of the total CCA in the block. Ground water irrigation coverage is 10% in the block. About 1888ha area has been brought under CCA by surface and ground water irrigation network**.** Hence, ground water irrigation coverage is poorly developed in Sahid Matangini block.

Surface irrigation network comprises tanks, surface flow and lift irrigation. As per the District Statistical Handbook, 2014,canal network is not reported in the block. A considerable area is brought under irrigation by numbers of tanks. Surface flow, lift irrigation comprises other mode of surface irrigation networks in the block.

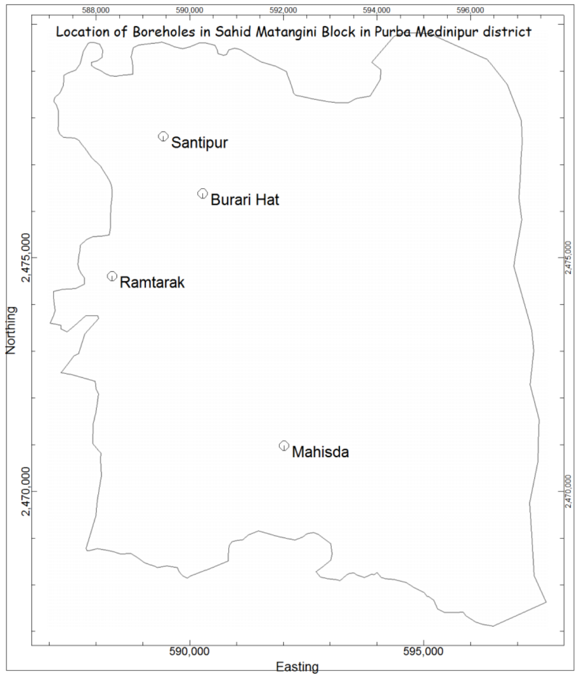
Ground water irrigation is limited and is accomplished mainly through limited shallow tube wells and deep tube wells. The CCA created by about 7shallow tube wells is 45haand by 10 deep tube well 141ha. The command area of STW and DTW is 5-7 ha and 15-20 ha respectively.

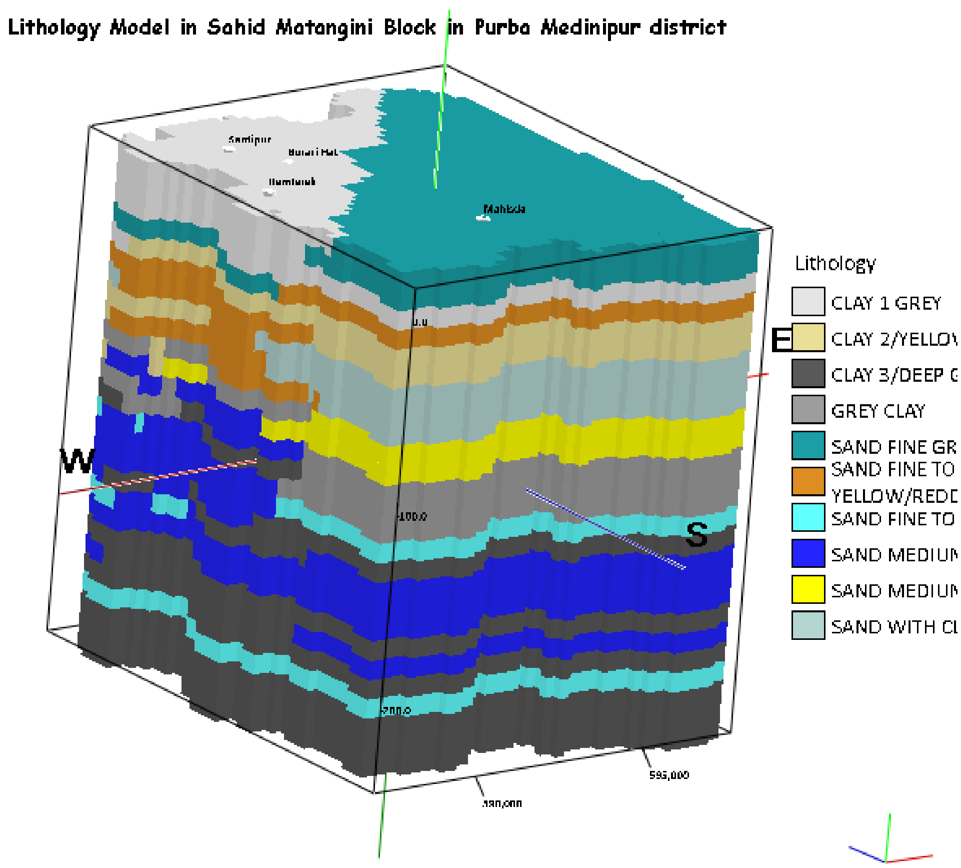
Table 18.4 CCA Created by Different Sources in the block (2013-14)

Block Name	Dugwell		Shallow Tubewell		Medium Tubewell		Deep Tubewell		Surface Flow		Surface Lift		CCA(ha.)		Total CCA(ha.)
	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	Ground Water	Surface Water	
Sahid Matangini	1.00	10.00	7.00	44.90	0.00	0.00	10.00	141.00	10.00	85.01	154.00	1606.94	195.90	1691.95	1887.85

18.5 Geology and Sub-Surface Geology

The block is covered by Holocene sediments. The newer alluvium of Holocene age is underlain by Pleistocene Quaternary sediments. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt. Departments, the actual lithology and interpreted aquifer models are prepared, and aquifer systems has been classified.

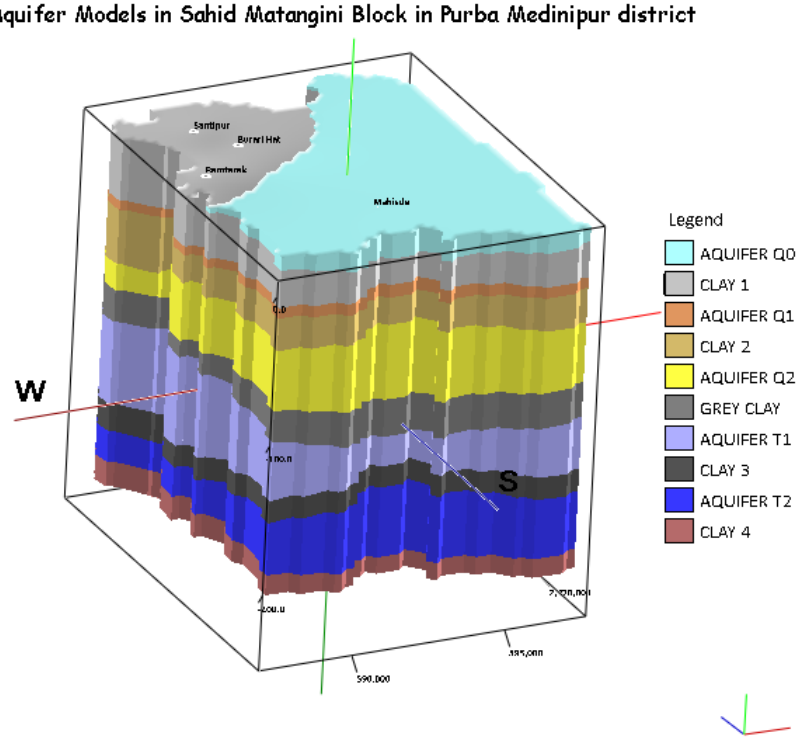

Location of Boreholes in Sahid Matangini Block in Purba Medinipur district
Santipur
Burari Hat
Ramtarak
Mahisda
Northing
Easting
590,000
595,000
2,475,000
2,470,000


Lithology Model in Sahid Matangini Block in Purba Medinipur district
Lithology
CLAY 1 GREY
CLAY 2/YELLOW
CLAY 3/DEEP G
GREY CLAY
SAND FINE GR
SAND FINE TO YELLOW/REDD
SAND FINE TO
SAND MEDIUM
SAND MEDIUM
SAND WITH CL
W
E
S
-100.0
-200.0
595,000

The lithology model reveals that the block is overlain by thick surface clay of25-30 m thick. The surface clay is mostly gray in colour representing younger alluvium. In the southern part of the block around Mahisda area impersistent discontinuous fine gray sands are found which is followed down by the gray clay. The lithology is represented by alternate sequence of sands of fine to medium and coarse and clay. The younger alluvium is underlain by fine to medium yellow coloured older alluvium sands separated by clay lenses. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and tertiary boundary is marked by occurrences of thick gray clay. Tertiary gray clay is thick and consistent and is found to occur at an average depth of 98-120 mbgl in the block. The average thickness of the Tertiary clay is 22m. Below the gray tertiary clay fine to medium grained greyish white sands of considerable thickness alternating with intervening clay constitute the Tertiary sedimentation within the explored depth.

18.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:

Aquifer Models in Sahid Matangini Block in Purba Medinipur district



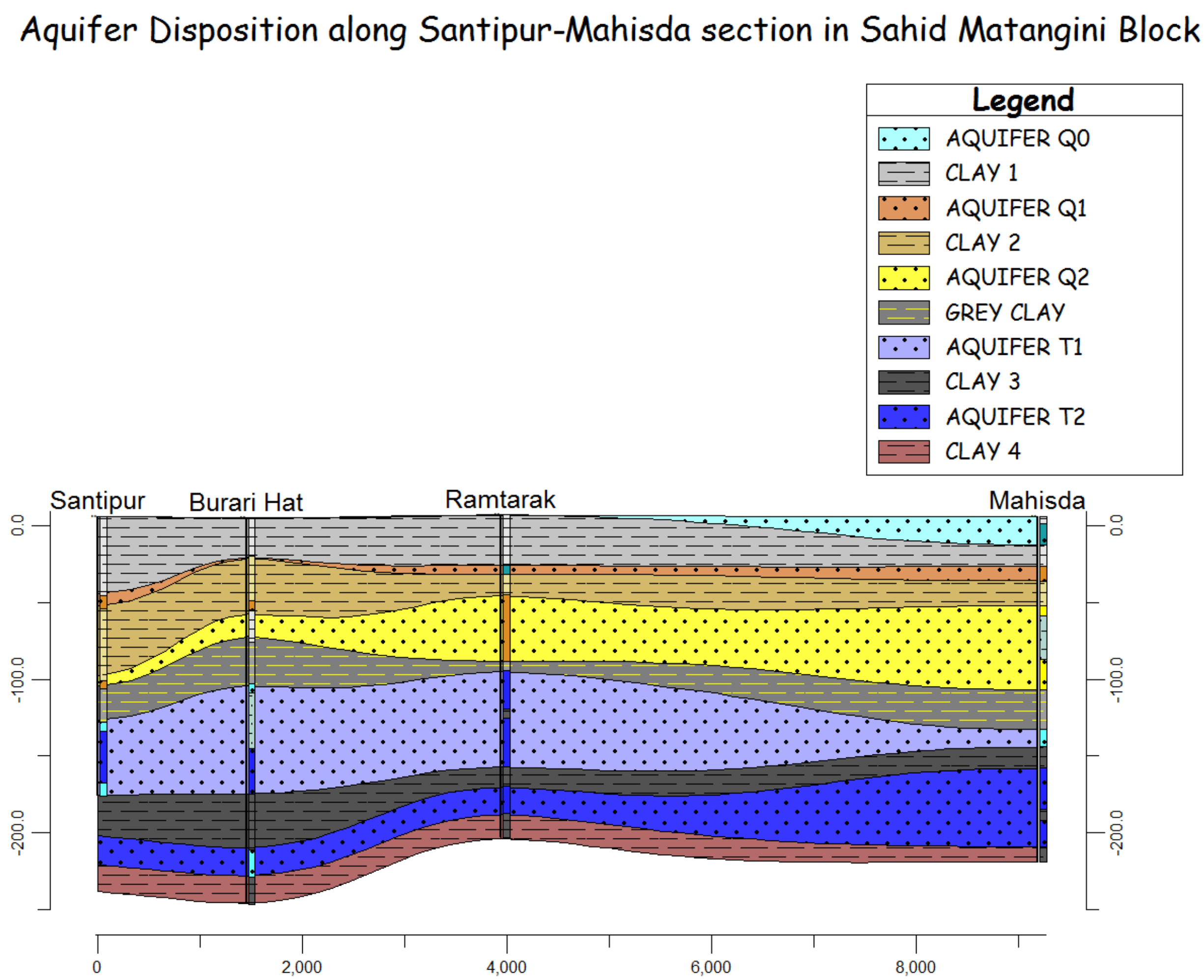


Table 18.5 Disposition of Aquifers and Q/T Boundary in Sahid MatanginiBlock

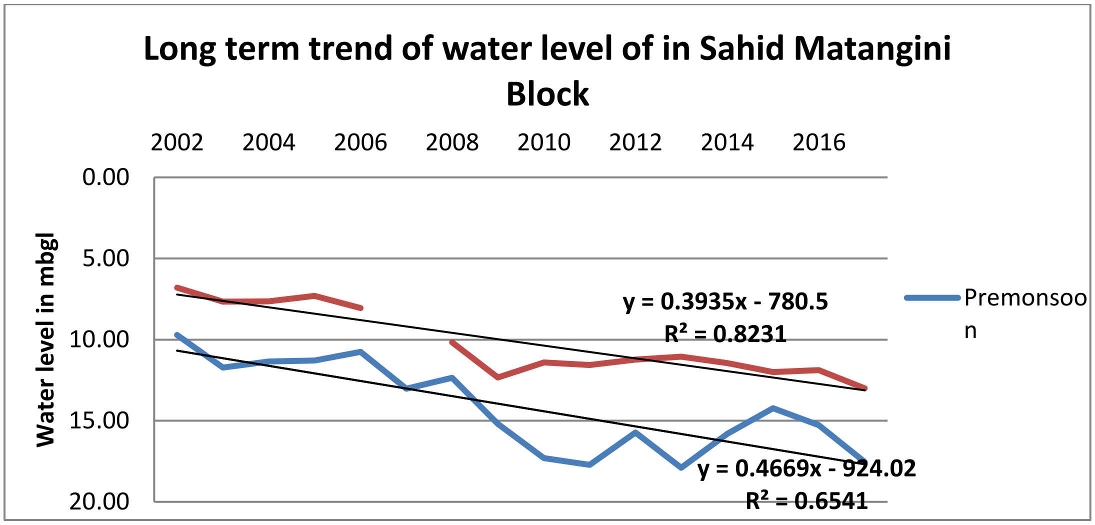
Block	Quaternary Aquifers						Q/T Boundary			Tertiary Aquifers					
	Q1			Q2						T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Tamluk	34.75	41	8.33	68.75	98.75	30	98.75	120.25	21.50	120.25	168.75	48.5	185.33	214.33	29

The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. The cumulative thickness of Tertiary aquifer in the area is more (75m) than that of quaternary aquifers (40 m) within the explored depth of 225 m in the block. The 1st Quaternary aquifer of younger alluvium is comparatively less prominent and thin. The 2nd Quaternary aquifer mostly of older alluvium, on the other hand, is consistent throughout the block and is thick. The separating clay between two Tertiary aquifers (T1 and T2) is present throughout the block thus, T1 and T2 represent two aquifers within the Tertiary. The Tertiary is thick and potential with minor variation in the thickness across the block. Around Mahisda area thin discontinuous phreatic aquifer of fine sands are found to host few dug wells.

Ground Water Condition

Except in few patches where dug well zones exist, groundwater, in both quaternary and tertiary aquifer system is under semi-confined to con fined condition. Pre and post monsoon water level have been monitored from number of observation wells (150-220 m depth)in Tertiary aquifer systems. Due to the paucity of the working tube wells in the quaternary aquifer, the monitoring data from the quaternary aquifer was limited. The depth of the observation well in quaternary aquifer is SWID piezometer of 60 m depth. The data of CGWB and SWID has been compiled and long term water level 2002-2017 has been analyses from SWID data for Tertiary aquifer only. It is observed that Tertiary registers a long term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow from NW-SE and NE-SW. However, the flow pattern in the block is influenced by the development in the adjacent blocks i.e., Tamluk and Kolaghat.

Aquifer system	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m below msl)
Tertiary	6	16.5	12	46cm fall	39 cm fall	-9.5
Quaternary	1	15	11			



Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is very high about 170-200 m^3/hr with moderate drawdown of below 6 m. The specific capacity ranges between 35-43 m^3/hr/m drawdown.

***Aquifer* Wise Ground Water Resource Availability**

The aquifer which is proficiently developed in the block is the Tertiary aquifer. The Quaternary aquifers are also used in few areas. The shallow phreatic aquifer is insignificant and is not in use in general. The Quaternary and the Tertiary aquifers are in semi-confined to confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl, therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area.

Table 18.6 Details of resource available in Tertiary and Quaternary aquifer (in MCM) in Block

Resource Availability	Tertiary	Quaternary

Resource by Storage	3.6043	1.2188

Table 18.7 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in (m^{2}/day)	Annual Flow in MCM
Sahid Matangini	10.67	0.0003000	2000.00	2.34

18.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from Tertiary aquifers the following chemical parameters are detected in Sahid Matangini block.

Table 18.8 Results of Chemical analysis of Tertiary aquifer in Sahid Matangini

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO3	HCO3	TA as CaCO3	Cl	SO4	NO3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO4	Fe
1	Mahisda	Sahid Matangini	Tertiary	7.93	744	bdl	354	290	14	15	7	8	1	140	97	7.8	4.6	bdl
2	Dariala	Sahid Matangini	Tertiary	8.01	777	bdl	325	397	57	43	31	66	2	175	92	8	2.3	10.53
3	Chatra	Sahid Matangini	Tertiary	7.62	614	bdl	235	287	60	15	12	68	2.4	180	52.9	7.8	6.7	0.52

The water from Tertiary is fresh. The concentration of Fe in ground water is reported much higher than the permissible limit in few cases. The water is mostly sodium bi-carbonate water.

18.8 Ground Water Resource Enhancement and Management Plan:

18.8.1 Ground Water Management Plan for drinking purposes

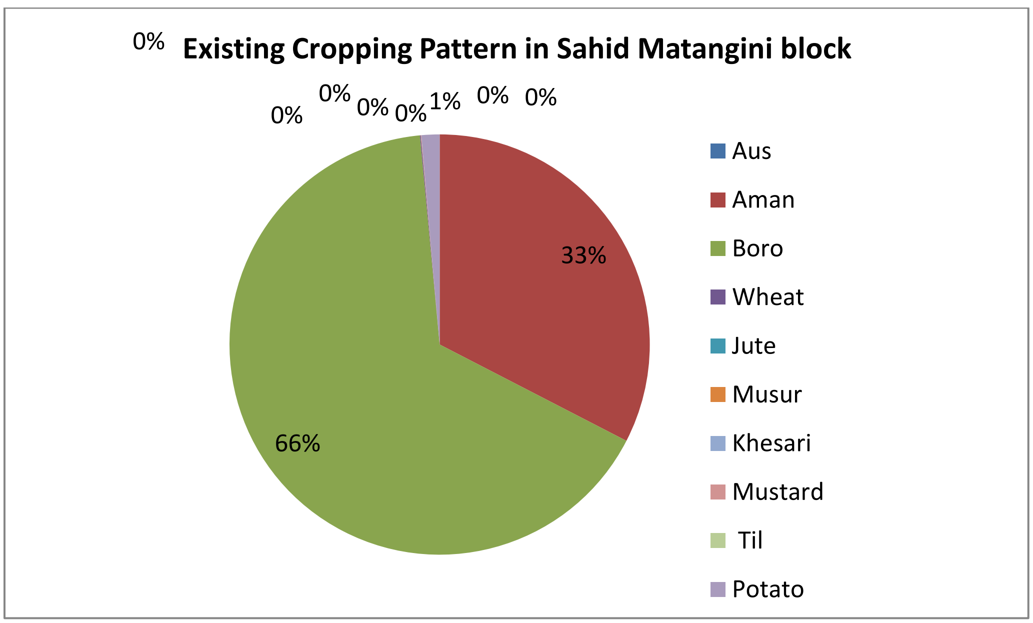
PHED, Govt. of West Bengal is entrusted for supply of drinking water in the block. Besides spot sources of hand pumps, mark II tube wells PHED has so far commissioned 2 no ground water-based water supply schemes and 2more ground water based schemes are under commissioning in the block. It has been assessed that total covered population through these schemes is about 89899. Therefore, 109311 remaining population need to be brought under water supply schemes for which about 1.5959MCM water is required. Since both the aquifers yields fresh water, therefore, following the prevailing practices in the block both the Quaternary and the Tertiary aquifer may be utilized to cater the remaining need of drinking water supply in the block. Thus, 2 drinking water tube wells in Tertiary and 4 tube wells in the Quaternary may further be constructed in phases to meet the demand from ground water resources. Therefore, further development of this aquifer will definitely affect the ground water regime in the area. It is observed that the probable decline of piezometric surface in Tertiary is 27 m and in Quaternary aquifer would be 18 m. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation should always be compensated by construction of suitably design artificial recharge structures in respective aquifers.

Table 18.9 Development Proposal of Tertiary Aquifers with implication on Piezometric Surfaces of Each Aquifer

Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncovered population @40lpcd in MCM	Annual resource proposed to be utilized from Quaternary Aquifer in MCM	Annual resource proposed to be utilized from Tertiary Aquifer in MCM	Total annual unit draft of one TW in MCM (considering average discharge of Quaternary and 8 hrs/day running)	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary and 8 hrs/day running)	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquifer	Decline of piezometric surface in Quaternary Aquifer (in m)	Decline of piezometric surface in Tertiary aquifer(in m)
Sahid Matangini	97.82	1.5959	0.6384	0.9576	0.1314	0.3504	4	2	18 .33	27.50

18.8.2 Management Plan for irrigation:

Present cropping pattern in the block: The major crop in the block is boro paddy which accounts for 66% of total crops in the block, other includes rain fed aman paddy (33%). The other crops like wheat , mustard, musur etc. re negligible in the block except potato which accounts for 1% total cultivable area.



The cultivable area of the block is 6846 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA in the block is 1888 ha. Further, 4958ha area is to be brought under irrigation coverage in the blocks. The irrigation tube wells are not very common in the block. However, the existing tube wells are concentrated within the depth range of 100 m. The available resource both in Quaternary and Tertiary aquifer in the block is limited. Tertiary aquifers in the block is under semi confined to confined condition and witnesses steady decline of water level therefore, further development of irrigation tube wells is not recommended. In contrary to these the trivial modification of cropping pattern may brought more area under irrigation in the blocks, therefore increases the intensity of cropping. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 579.60 ha m of water. This volume of water is used to cultivate oilseeds (sunflower/ mustard), wheat, pulses etc. as per the prevailing cropping pattern in the block. **Thus, 1052 ha effective increase in irrigation area** may be created by change in cropping pattern. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability.

Table 18.10 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation				Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction(ha)	Volume of Irrgation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor:30 cm)	Floriculture (Bell, Merrigold, tuberose) (Delta factor:22.5 cm)	Total additional area created in ha	Effective Increase in area(ha)
Sahid	4826	1.2	4343	579.60	515.20	483.00	536.67	--	1534.87	1052.27

Matangini										

18.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non-committed surface runoff produced in the block is 15.01 MCM. The non-committed flow is proposed to be utilized to recharge both Quaternary and Tertiary aquifers in the block. As per the available storage space 0.3250 MCM and 0.3335 MCM water is required to fill the available storage space in tertiary aquifers and quaternary aquifer respectively. Therefore, 24 and 25 injections well with roof top rain water harvesting structures is recommended in two aquifer system respectively. The successful implementation of recharge structures may raise the piezometric surface about 9-10 m. Further, in case of construction of more tube wells in Tertiary and Quaternary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated.

The remaining non committed runoff, 14.3554MCM is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 287 storage / irrigation tanks have been proposed. These tanks can generate additional irrigation potential of 2153 ha considering average delta factor of 50 cm for rabi crops, vegetable, etc. Therefore, by change in cropping pattern and utilizing the non-committed runoff for tank irrigation total 3205 ha further irrigation potential can be created. Thus,66% of the remaining area in the block may be brought under irrigation. The roof top rainwater harvesting structures with suitably design injection wells may be proposed to construct in the urban area/census towns in primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with 1-2 irrigation tanks for harvesting of surface runoff at suitable locations and for subsequent irrigation uses.

Summary of Management Plan:

- *Drinking water tube wells have been recommended in Tertiary aquifer to meet the uncovered demand from ground water sources. 6 drinking water tube wells are recommended.*
- *The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of 24 injection wells in Tertiary and 25 in Quaternary aquifers.*
- *Further construction of irrigation tube wells is restricted. The boro area may be reduced by 10% of existing area, and the surplus water may be used to irrigate pulses, oilseed and floriculture crops. Thus additional 1052 ha irrigation potential can be generated.*
- *The non committed runoff may be used for irrigation tanks. Considering capacity of one tank as 0.05 MCM,287 irrigation tanks are proposed, preferably one- two in each habitation in the block. This will generate additional irrigation potential of 2153 ha. Thus, the additional irrigation potential created by change in cropping pattern and by harvesting surface runoff will bring 66% of the remaining cultivable area in the block under irrigation coverage.*

Table 18.11 Proposed Conservation and Recharge Structures based on the available non committed surface runoff and available storage space

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Vol of water kept for conservation/storage tanks in MCM (3-(4+5))	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks (6/8)	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary (4/9)	No of RTRWH with injection well required for Quaternary (5/9)
Sahid Matangini	97.82	15.01	0.3250	0.3335	14.3554	0.05	287	0.0133072	24	25

19.0 MANAGEMENT PLAN OF TAMLUK BLOCK

19.1 Location, Demography and Rainfall

Tamluk is located at 22.30°N latitude and 87.92°E longitude Bounded in the east by Sahid Matangini Block and Rupnarayan river, in the west by Moyna block, in the north by Panskura block and in the south by Nandakumar Block of Purba Medinipur district.

- Subdivision: Tamluk
- Sub basin: Rupnarayan
- Geographical Area:
- Tamluk Block: 113.07 sq km.
- Tamluk Municipality: 17.86 sq.km
- Population (2011 Census)

Table 19.1 Total population of the Block

	Rural Population	Urban Population	Total
Block	207064	10712	217776
Municipality		65306	65306

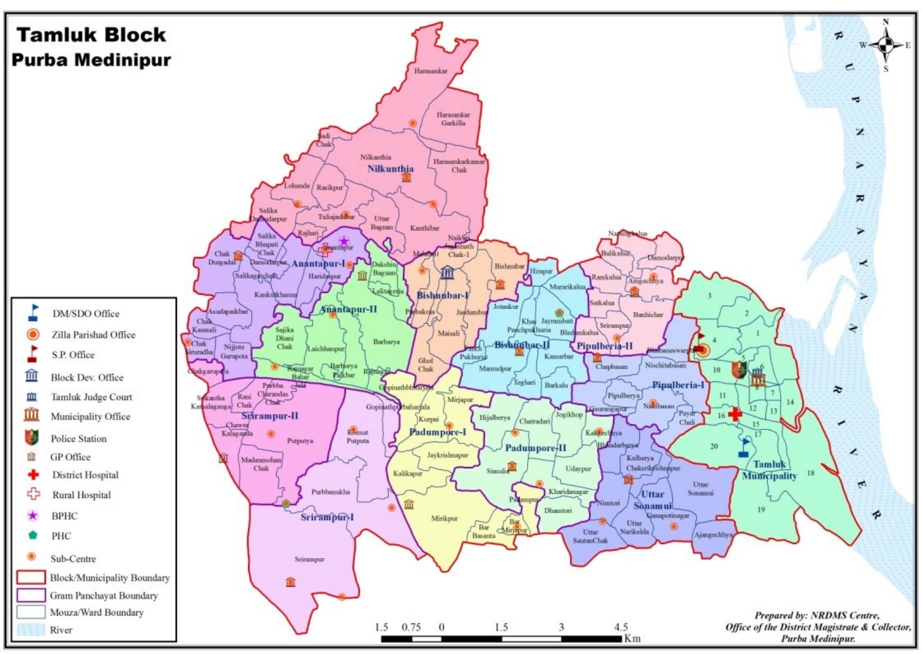


Figure 19.1 Gram-Panchayet and Mouza Map of Tamluk Block

The block comprises 12 Gram Panchayets, 100 villages, 187 habitations and 49046 households.

Table 19.2 Basic Demographic Detail of Tamluk Block (recent data) on the basis of projection from 2011 census data

S.No.	Panchayat	Villages	Habitations	Households	Population
1	Anantapur-i	11	16	3878	17783
2	Anantapur-ii	8	15	4110	19882
3	Bishnubar-i	7	13	3363	14892
4	Bishnubar-ii	10	16	3240	14561
5	Nilkunthia	11	22	7221	30861
6	Padumpur-i	9	20	4563	21576
7	Padumpur-ii	8	14	4122	19229
8	Pipulberia-i	7	11	3551	16260
9	Pipulberia-ii	9	12	2675	12436
10	Srirampur-i	4	15	4334	18954
11	Srirampur-ii	7	14	3725	15212
12	Uttar Sonamui	9	19	4264	19866
	Total	**100**	**187**	**49046**	**221512**

Source: PHED, Govt of WB, Website

- **Normal Annual Rainfall** in the district: 1663.40 mm

Table 19.3 Annual Rainfall Variation

Year	2010	2011	2012	2013	2014	Average Annual Rainfall
Annual Rainfall in mm	1244	1538	1342	2078	1729	1586

19.2 Physiographic and Drainage:

The block is a part of lower Gangetic plain and almost entire blocks is in Rupnarayan sub-basin. The river Rupnarayan which is flowing in SE direction along the eastern boundary of the block controls the drainage network of the block. The tributaries of Rupnarayan also constitute the drainage volume of the block. Average elevation is 7 m amsl. The dominant soil type of the block is very poorly drained impermeable clayey soil.

The block is underlain by fluvial alluvium of Quaternary and Tertiary age.

19.3 Land use pattern:

The nature of soil types and water availability principally influence the land use pattern of the block.

Table 19.4 Details of Land use pattern of block (area in ha)

Name of the block	Reporting area	Forest area	Area under non-agriculture wastes	Barren and un-culturable lands	Permanent pastures and grazing lands	Land under misc tree crops	Culturable wastes	Fallow land Other than current fallow	Current fallow	Net area sown
Tamluk	13291	0	5928		5	40	1			7317

19.4 Agriculture and Irrigation:

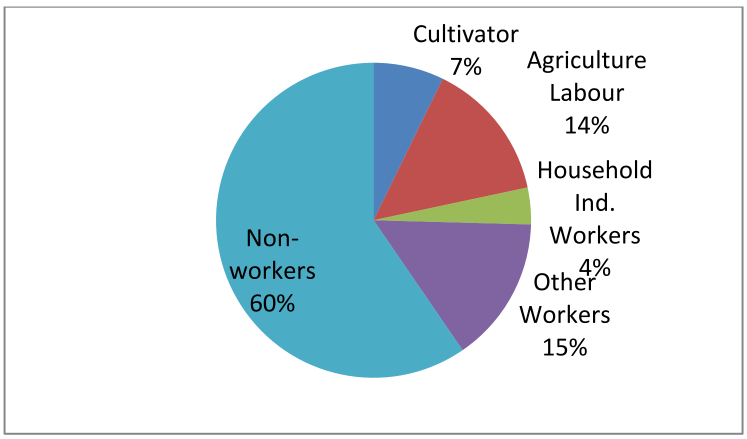


Figure 19.2 Distribution of persons engaged in agriculture and other workers/non workers in the Block

In Tamluk block, 60% of total population is non workers. It is evident from the above diagram that 21% of the total workers in the block are engaged in agriculture either as cultivator or as agriculture labour. 4% comprises Household industrial workers and 15% comprises other workers.

Irrigation in the block is achieved by surface and ground water sources. The Culturable Command area (CCA) created by surface water resources constitute 77.58% of the total CCA in the block. ground water irrigation coverage is 22% in the block. About 2750 ha area has been brought under CCA by surface and ground Water irrigation network**.** Therefore, ground water irrigation coverage is not well developed in Tamluk block

Surface irrigation network comprises tanks, surface flow and lift irrigation. As per the District Statistical Handbook, 2014 canal network is not reported in the block. A considerable area is brought under irrigation by 1850 numbers of tanks. Surface flow, lift irrigation comprises other mode of surface irrigation networks in the block.

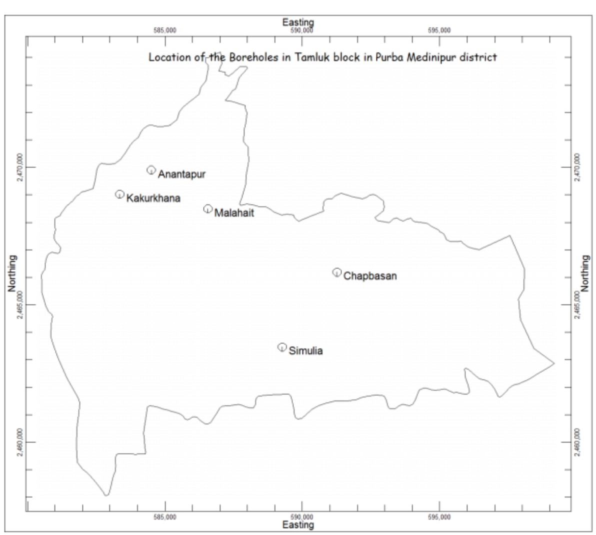
Ground water irrigation is limited and is accomplished mainly through shallow tube wells and limited numbers of deep tube wells. The CCA created by about 40 shallow tube wells is 167 ha and by 15 deep tube well 359 ha. The command area of STW and DTW is 5 ha and 25 ha respectively.

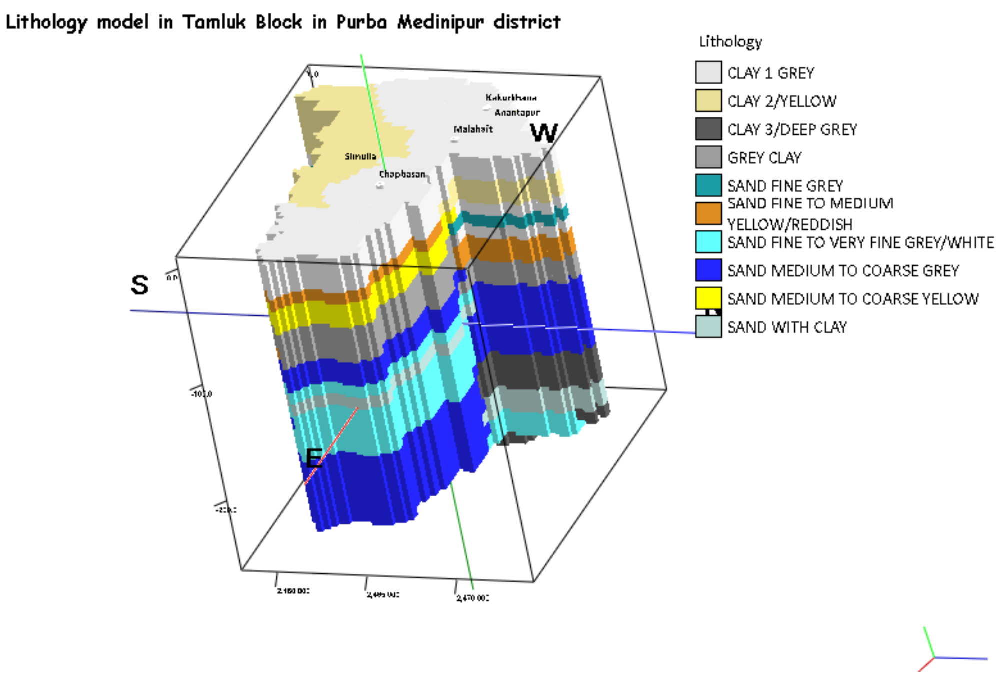
Table 19.5 CCA Created by Different Sources in the block

Block Name	Dugwell		Shallow Tubewell		Medium Tubewell		Deep Tubewell		Surface Flow		Surface Lift		CCA(ha.) Total CCA(ha.)		
	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	No.	CCA(ha.)	Ground Water	Surface Water	
Tamluk	2.00	19.00	40	167.32	3	71.00	15.00	359.20	10.00	118.18	240	2015.38	616.52	2133.56	2750

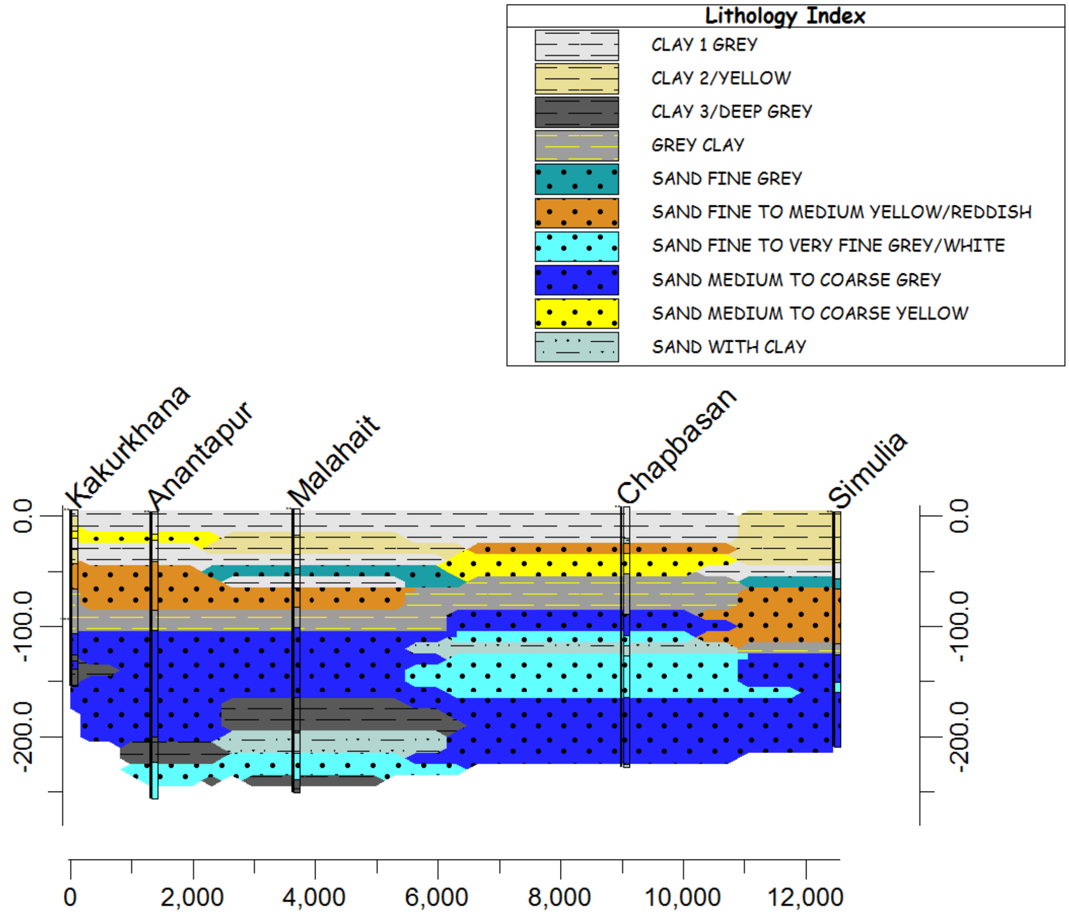
19.5 Geology and Sub-Surface Geology

The block is covered by Holocene sediments. The newer alluvium of Holocene age is underlain by Pleistocene Quaternary sediments. The Quaternary alluvium is further underlain by Mio-Pliocene Tertiary sediments. The boundary between Quaternary and Tertiary is characterized by occurrences of thick consistent grey clay. Based on the available ground water exploration data of CGWB and State Govt. Departments, the actual lithology and interpreted aquifer models are prepared, and aquifer systems has been classified.



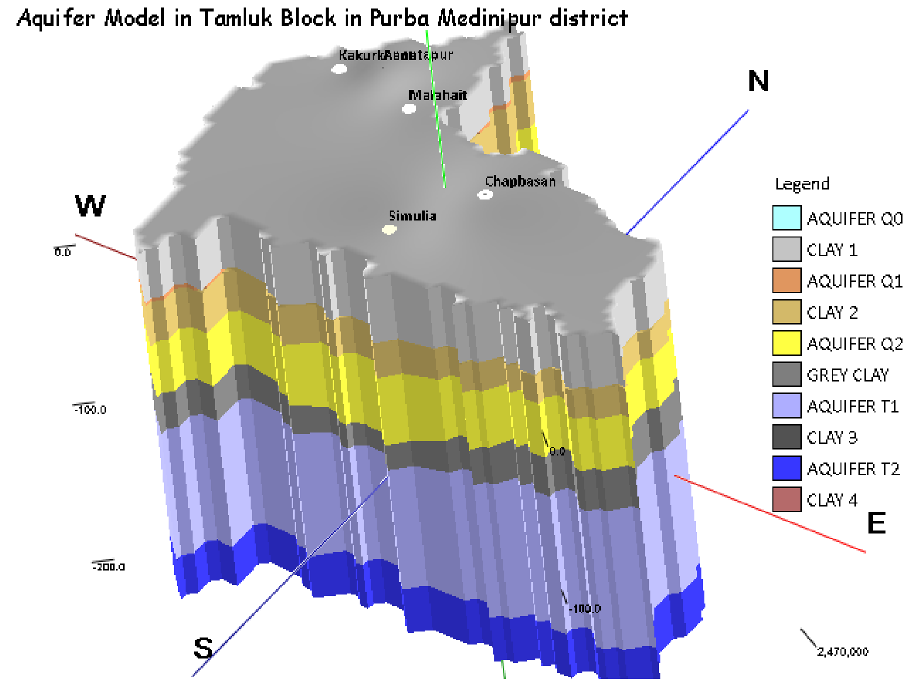

Lithology model in Tamluk Block in Purba Medinipur district
Anantapur
Malahsit
Shimulia
Chapbasan
S
W
E
Lithology
CLAY 1 GREY
CLAY 2/YELLOW
CLAY 3/DEEP GREY
GREY CLAY
SAND FINE GREY
SAND FINE TO MEDIUM YELLOW/REDDISH
SAND FINE TO VERY FINE GREY/WHITE
SAND MEDIUM TO COARSE GREY
SAND MEDIUM TO COARSE YELLOW
SAND WITH CLAY

Lithology Section along Kakurkhana-Chapbasan-Simulia in Tamluk Block



The lithology model reveals that the block is overlain by thick surface clay of 20-25 m thick. The surface clay is mostly gray in colour representing younger alluvium, however in few patches around Simulia village in the southeastern parts of the block yellow clay of older alluvium origin is found at the surface. The lithology is represented by alternate sequence of sands of fine to medium and coarse and clay. Quaternary sediments are followed by Tertiary clay and sands. The Quaternary and tertiary boundary is marked by occurrences of thick gray clay. Tertiary gray clay is thick and consistent and is found to occur at an average depth of 82-106 mbgl in Tamluk block. The average thickness of the Tertiary clay is 24 m.

19.6 Hydrogeology, Aquifer Portrayal (Aquifer Maps) and Ground Water Resources:



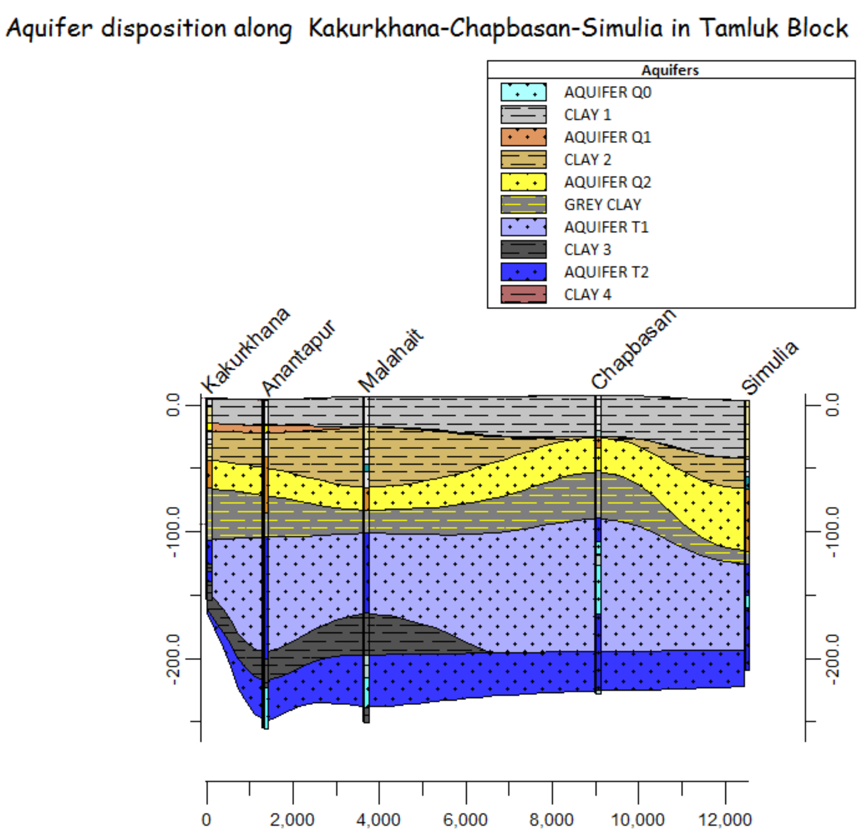


Table 19.6 Disposition of Aquifers and Q/T Boundary in Tamluk Block

Block	Quaternary Aquifers						Q/T Boundary			Tertiary Aquifers					
	Q1			Q2						T1			T2		
	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness	From	To	Thickness
Tamluk	24.67	31.67	14.00	45.17	82.17	32.40	82.17	106.00	23.83	105.83	188.67	82.83	199.33	224.67	37.50

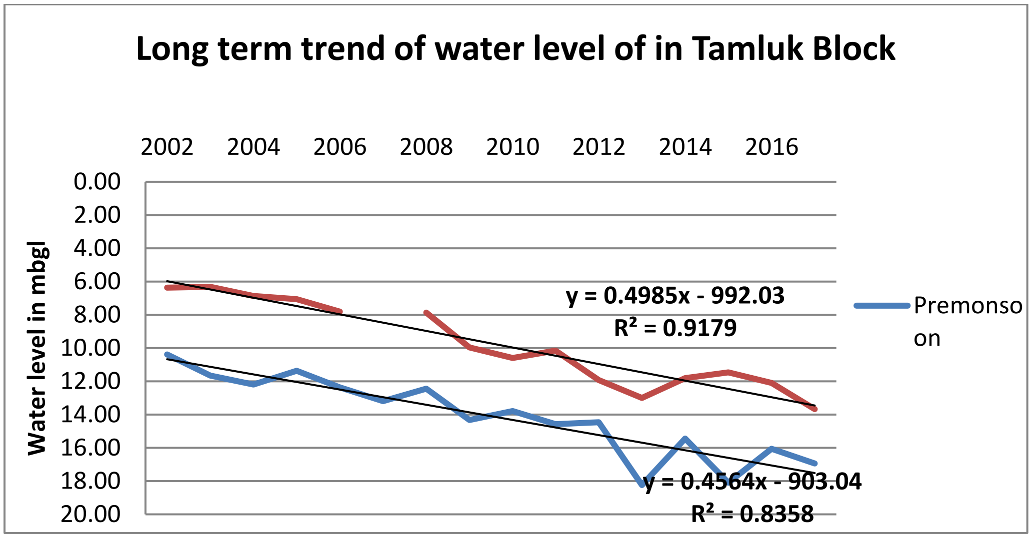
The disposition and subsequent correlation of lithological characteristics in the block reveals two principal aquifer systems each with two aquifer components Q1 and Q2 in Quaternary system and T1 and T2 in Tertiary system. The cumulative thickness of Tertiary aquifer in the area is more (120 m) than that of quaternary aquifers (46 m). The Tertiary aquifers are very thick in the block. The 1st Quaternary aquifer of younger alluvium is not well developed throughout the block except in Kakurkhana, Anantapur area in the north eastern part of the block. The 2nd Quaternary aquifer mostly of older alluvium, on the other hand, is consistent throughout the block. The separating clay between two Tertiary aquifers (T1 and T2) is present only in the eastern part of the block and in rest of the block the single Tertiary aquifer is observed.

Ground Water Condition

Groundwater, in both quaternary and tertiary aquifer system is under confined condition. Pre and post monsoon water level have been monitored from number of observation wells in Tertiary aquifer systems. Due to the paucity of the working tube wells in the quaternary aquifer, the monitoring from the quaternary aquifer system was not possible. The data of CGWB and SWID has been compiled and long term water level 2002-2017 has been analyses from SWID data for Tertiary aquifer only. It is observed that Tertiary registers a long term steady fall both in pre and post monsoon season. The piezometric surface has been prepared wrt the mean sea level indicates dominant flow from NW-SE and NE-SW from 10 m below sea level to 19 m below sea level in Tertiary aquifers. The ground water flow is influenced by local ground water development in the block.

Aquifer system	No of monitoring stations	Pre monsoon SWL mbgl	Post monsoon SWL mbgl	Pre monsoon trend cm/year	Post monsoon trend cm /year	Pre-monsoon Piezometric surface (m

						below msl)
Tertiary	10	14.5-24.5	12.8-16.2	45 cm fall	49 cm fall	-10 to-19.4 m



Discharge and Specific Capacity:

The discharge data compiled from the CGWB and State Govt drinking water and irrigation wells revels the average discharge of the Tertiary Aquifer is about 125-230 m^3/hr with moderate drawdown of 2.5-5 m. The specific capacity ranges between 25-75 m^3/hr/m drawdown. Irrigation shallow tube wells in the quaternary aquifer is rare.

***Aquifer* Wise Ground Water Resource Availability**

The entire block is under confined condition. Therefore, following GEC, 2015 methodology for assessment of resource in confined parts the storage concept is applied. Since, both pre-monsoon and post monsoon piezometric surfaces are below msl, therefore the resource for dynamic parts of the confined aquifers is not assessed. The resource by storage in confined aquifer is considered as the total available resource in the area.

Table 19.7 Details of resource available in Tertiary aquifer (in MCM) in Block

Resource Availability	Tamluk block	Tamluk Municiaplity
Resource by Storage	3.5423	0.5595

Table 19.8 Estimation of Flow in Tertiary Aquifer applying TIL method

Block	Maximum length of flow path in km (L)	Average Hydraulic Gradient (I)	T in (m^2/day)	Annual Flow in MCM
Tamluk	15.67	0.000368	2000.00	4.21

19.7 Chemical Quality of Ground Water:

Based on chemical analysis of ground water from Tertiary aquifers the following chemical parameters are detected in Tamluk block.

Table 19.9 Results of Chemical analysis of Tertiary aquifer in Tamluk

Sl. No	Village	Block	Aquifer	pH	EC µS/cm at 25°C	CO_3	HCO_3	TA as CaCO3	Cl	SO_4	NO_3	Ca as Ca	Mg as Mg	TH as CaCO3	Na	K	PO_4	Fe
1	Chapbasan	Tamluk	Tertiary	8.01	1685	bdl	476	390	302	8	10	20	7	215	276	19.5	0.31	1.51
2	Simulia	Tamluk	Tertiary	7.92	834	bdl	378	310	71	4	2	52	17	110	138	7.8	1.2	1
3	Anantapur zoneII	Tamluk	Tertiary	8	2416	bdl	580	475	498	30	5	14	2	315	403	15.6	1.6	1.12
4	Kakurkhana	Tamluk	Tertiary	7.89	891	bdl	415	340	43	9	11	18	5	100	140	31.2	1.5	0

The water from Tertiary is fresh except one sample at Anantpur of PHED WSS. The concentration of Fe in ground water is slightly higher than the permissible limit. The water is mostly sodium chloride and sodium bi-carbonate water.

19.8 Ground Water Resource Enhancement and Management Plan:

19.8.1 Ground Water Management Plan for drinking purposes

PHED, Govt. of West Bengal is entrusted for supply of drinking water in the block. Besides spot sources of hand pumps, mark II tube wells PHED has so far commissioned 7 no ground water based water supply schemes and 1 more ground water based schemes are under commissioning in the block. It has been assessed that total covered population through these schemes is about 167381. Therefore, 115701 remaining population need to be brought under water supply schemes for which about 1.6892 MCM water is required. As per the prevailing practices in the block the Tertiary aquifer may be utilized to cater the remaining need of drinking water supply in the block. Thus, 5 drinking water tube wells in Tertiary aquifer may further be constructed in phases to meet the demand from ground water resources. Therefore, further development of this aquifer will definitely affect the ground water regime in the area. It is observed that the probable decline of piezometric surface in Tertiary is 36 m. Therefore, installation of tube wells for drinking water, being foremost priority as per National Water Policy, may not be avoided, but keeping in view on the further lowering of piezometric surface the installation should always be implemented in phases with precaution. Any installation should always be compensated by construction of suitably design artificial recharge structures in respective aquifers.

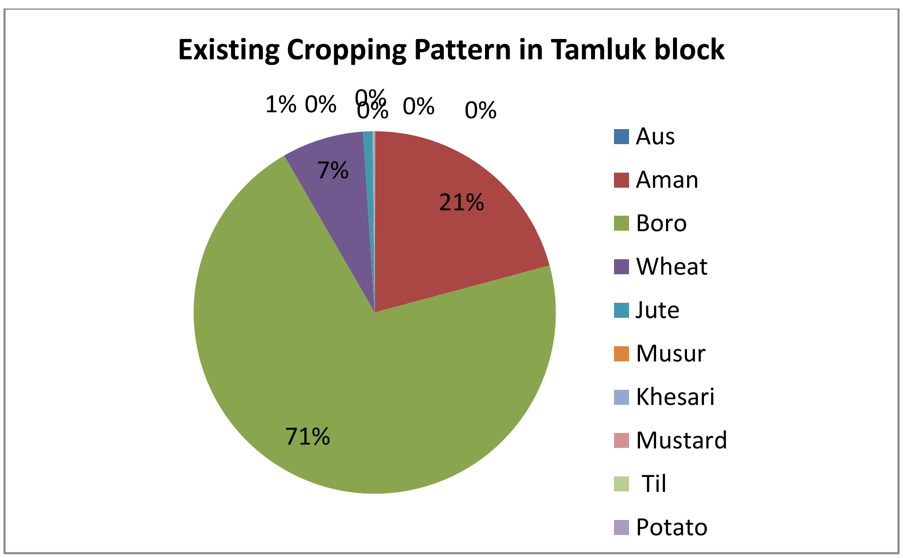
Table 19.10 Development Proposal of Tertiary Aquifers with implication on Piezometric Surfaces of Each Aquifer

Name of the block	Geographical area (in Sq.Km.)	Annual Resource required to cater the uncovered population	Annual resource proposed to be utilized from Quaternary Aquifer in MCM	Annual resource proposed to be utilized from Tertiary Aquifer in MCM	Total annual unit draft of one TW in MCM (considering average discharge of	Total annual unit draft of one TW in MCM (considering average discharge of Tertiary	No of tube well required in Quaternary aquifer	No of tube well required in Tertiary aquifer	Decline of piezometric surface in Quaternary Aquifer (in m)	Decline of piezometric surface in Tertiary aquifer(in m)

		@40lpcd in MCM			Quaternary and 8 hrs/day running)	and 8 hrs/day running)				
Tamluk	113.07	1.6892346	0	1.6892346		0.3504	0	5		36.24

19.8.2 Management Plan for irrigation:

Present cropping pattern in the block: The major crop in the block is boro paddy which accounts for 71% of total crops in the block, other includes rain fed aman paddy (21%) , wheat (7%) and jute. Mustard , musur, Til, Potato is negligible.



The cultivable area of the block is 7358 ha. The culturable command area (CCA) has been created by both ground water and surface irrigation networks. Total CCA in the block is 2750 ha. Further, 4608 ha area is to be brought under irrigation coverage in the blocks. The irrigation tube wells are not common in the block. However, the existing tube wells are concentrated within the depth range of 100-200 m depth.

The quaternary aquifer in the block is reported to be brackish to saline in nature and in general not developed at all for irrigation uses. Tertiary aquifers in the block is under semi confined to confined condition and witnesses steady decline of water level therefore, further development of irrigation tube wells is not recommended. In contrary to these the trivial modification of cropping pattern may bring more area under irrigation in the blocks, therefore increases the intensity of cropping. Here, the boro area is proposed to be reduced 10% of the existing area, which surplus 585.60 ha m of water. This volume of water is used to cultivate oilseeds (sunflower/ mustard), wheat, pulses etc. as per the prevailing cropping pattern in the block. **Thus, 1062.26 ha effective increase in irrigation area** may be created by change in cropping pattern. However, further modification of proposed crops is encouraged based on local agricultural development/constrains and social acceptability. The cash crops like pan (betel leaf) production may also be attempted with the surplus water in favourable condition.

Table 19.11 Proposed Intervention in Irrigation Practice in the study area to increase Effective Irrigation Coverage maintaining the present Ground Water Draft

Present area under Boro and proposed reduction of 10% of Boro area					Additional area brought under coverage of other crops with the saved water from reduction of boro cultivation				Increase in area under Irrigation coverage by reducing 10% boro Cultivation	
Block	Area under boro (ha)	Water column for boro paddy	Area under boro after 10% reduction (ha)	Volume of Irrgation water saved (ham)	Wheat (Delta factor:37.5 cm)	Mustard/Sunflower (Delta factor:40 cm)	Pulses (Delta factor:30 cm)	Floriculture (Bell, Merrigold, tuberose) (Delta factor:22.5 cm)	Total additional area created in ha	Effective Increase in area(ha)
Tamluk	4885	1.2	4397	585.60	520.53	488.00	542.22	--	1550.76	1062.26

19.8.3 Management Intervention through Harvesting of Surface Runoff and Artificial Recharge

It has been estimated by applying Dhruvanarayana, 1993, that the non-committed surface runoff produced in the block is 17.35 MCM, besides about 2.75 MCM runoff is also generated in Tamluk municipality area. The non-committed flow is proposed to be utilized to recharge the depleted Tertiary aquifers in the block. As per the available storage space 0.3696 MCM and 0.0584 MCM water is required to fill the available storage space in tertiary aquifers in block and in municipal area respectively. Therefore, 28 and 4 injections well with roof top rain water harvesting structures is recommended in the rural area of the blocks and in municipal area respectively. The successful implementation of recharge structures may raise the piezometric surface about 9-10 m. Further, in case of construction of more tube wells in Tertiary and Quaternary aquifers as per recommendation, subsequent increase in recharge structures in the corresponding aquifers is also advocated.

The remaining non committed runoff, 16.9848 MCM is recommended to be utilized in storage tanks for generation of irrigation potential and thus, 340 storage / irrigation tanks have been proposed. These tanks can generate additional irrigation potential of 2548 ha considering average delta factor of 50 cm for rabi crops, vegetable, horticulture/ floriculture crops. Therefore, by change in cropping pattern and utilizing the non-committed runoff for tank irrigation total 3610 ha further irrigation potential can be created. Thus, 78% of the remaining area in the block may be brought under irrigation. The roof top rainwater harvesting structures with suitably design injection wells may be proposed to construct in the Municipality area in primary phases and subsequently may be extended to the rural area. On the other hands each habitation in the block may be provided with 1-2 irrigation tanks for harvesting of surface runoff at suitable locations and for subsequent irrigation uses.

Summary of Management Plan:

- *Drinking water tube wells have been recommended in Tertiary aquifer to meet the uncovered demand from ground water sources. 5 drinking water tube wells in Tertiary have been proposed.*
- *The present lowering of piezometric level and suspected lowering as an implication of construction of recommended tube wells to be mitigated by construction of 28 injection wells in block area and 4 injection wells in Municipal area with roof top harvesting arrangements.*
- *Further construction of irrigation tube wells is restricted. The boro area may be reduced by 10% of existing area, and the surplus water may be used to irrigate pulses, oilseed and floriculture crops. Thus additional 1062 ha irrigation potential can be generated.*
- *The non-committed runoff may be used for irrigation tanks. Considering capacity of one tank as 0.05 MCM, 340 irrigation tanks are proposed, preferably one- two in each habitation in the block. This will generate additional irrigation potential of 2548 ha. Thus, the additional irrigation potential created by change in cropping pattern and by harvesting surface runoff will bring 78% of the remaining cultivable area in the block under irrigation coverage.*

Table 19.12 Proposed Conservation and Recharge Structures based on the available non committed surface runoff and available storage space

Name of the block	Geographical area (in Sq.Km.)	Non-Committed surface runoff available (MCM)	Total surface runoff/water required to fill storage space in Tertiary (MCM)	Total surface runoff/water required to fill storage space in Quaternary (MCM)	Vol of water kept for conservation/storage tanks in MCM (3-(4+5))	Capacity of Conservation /Irrigation tanks MCM	Proposed no of storage tanks (6/8)	Volume of water harvested through RTRWH of 100 sq m roof area (area*total average annual rainfall * 0.8) in MCM	No of RTRWH with injection well required for Tertiary (4/9)	No of RTRWH with injection well required for Quaternary (5/9)
1	2	3	4	5	6	7	8	9	10	11
Tamluk	113.07	17.3544	0.3696		16.9848	0.05	340	0.0133072	28	
Tamluk Municipality	17.86	2.7412	0.0584		----	---	----	0.0133072	4	

DATA GAP ANALYSIS

20.0 DATA GAP ANALYSIS REPORT IN PARTS OF PURBA MEDINIPUR DISTRICT, WEST BENGAL, 2017-18

20.1 Introduction

Under National Aquifer Mapping Programme studies have been undertaken in Purba Medinipur district, West Bengal during 2017-18. The present study includes parts of the Purba Medinipur district comprising a mappable area of 1820 sq. km. in 13 blocks in Tamluk, Haldia and in parts of Contai Subdivision. The study area extends between 88°12’40”E to 87°38’15”E longitude and 21°43’30” N to 22°31’15” N latitude. The area falls in Survey of India topo-sheet no 73N/11, 73N/12, 73N/15, 73N/16, 73O/13, 79B/4.

The broad objective of the study is to establish the geometry of the underlying aquifer systems in horizontal and vertical domain, aquifer characterization, scope for development potential and prepare aquifer-wise management plan. The scope of the approach of the above studies includes data availability, compilation of the existing data, identification of gap of data wrt to exploration, water level, water quality and geophysical data, data generation, compilation and analysis, preparation of maps and finally formulation of management plan.

20.2 Data Availability

The available exploration data of CGWB in the respective blocks and topo-sheet within the study area has been compiled, plotted, and tabulated which is furnished in Figure 20.1 and table 20.1.

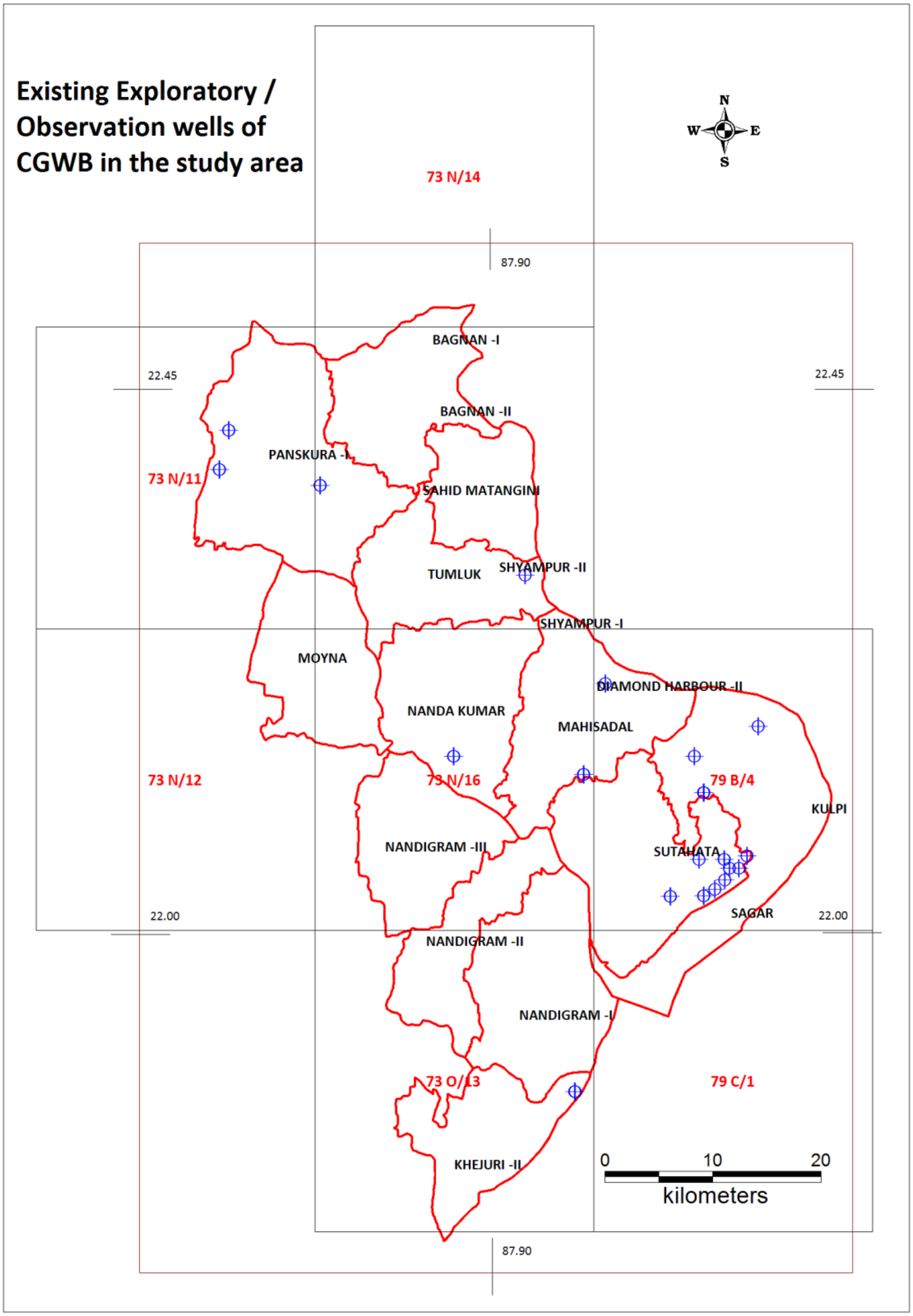


Figure 20.1 Existing EW/OWs of CGWB

Table 20.1 Existing Exploratory/Observation Wells of CGWB in the Study area

Sl__No_	Block	Location	Well_Type	Latitude	longitude	Drill_Depth__mbgl_	Well_Depth__mbgl	Zones tapped in m	Discharge__lps_	Drawdown in m	Transmissivity(m2/day)	Storativity
1	Haldia	Anchorage camp, Haldia (EW)	EW	22.0289	88.0958	457.2			39.88	17.5		
2	Haldia	Anchorage camp (EW) Haldia (EW)	EW	22.0289	88.0958	300	230.5	155.57-160.07,164.91-170.20,177.78-182.99,203.53-224.38				
3	Haldia	Durgachak	EW	22.0619	88.1347	304.7	140	55.47-64.01,102.41-108.59,116.46-121.05,130.25-136.55	38.48	15.67	265.48	
4	Haldia	Hadia Rly. Terminal	EW	22.0517	88.1194	365.8						
5	Haldia	IOC (Deposit Well)	Deposit Well	22.0592	88.1142	284	230	144.00-154.00,164.00-170.00,195.00-209.00,223.00-227.00	22.64	5.8	543	
6	Haldia	IOC (Pz)	Pz	22.0592	88.1142	296.8	231.5	137.00-149.00,161.50-173.50,216.50-228.50				
7	Haldia	Baganpara	Deposit Well	22.0344	88.1061	301	249.5	186.00-201.76,209.03-215.17,224.04-231.09,240.13-246.23	17.38	6.01		
8	Haldia	Port Trust Haldia Township	Deposit Well	22.0517	88.1275	250	225	144.00-161.00,170.00-173.00,212.00-222.00	33.81	6.48		
9	Haldia	Haldia Helipad	DEW	22.0284	88.066	400	230	188.00-194.00,220.00-228.00	25.3	7.68	789 (T)	

		(DEW)										
10	Haldia	Haldia Helipad (SEW)	SEW	22.0284	88.066	0	152	130.00-136.00,144.00-150.00		0		
11	Haldia	Haldia Oil Jetty	Deposit Well	22.0422	88.1147	301	233	184.17-195.15,197.15-202.67,206.52-215.69,220.19-230.19	24.79	8.18	280.5	
12	Haldia	Balughata (Pz), Haldia	Pz	22.0589	88.0917	295.85	225	137.00-149.00,161.00-173.00,210.00-222.00				
13	Sutahata	Gopalpur (EW)	EW	22.1692	88.145	304.7	153	84.00-92.00,96.80-99.90,107.20-117.60,137.00-149.90				
14	Khejuri-II block	Khejuri (DEW)	DEW	21.8664	87.9803	401.37	283	236.00-254.0,268.00-280.00	53.44		2444	6.8x10-4
15	Khejuri-II block	Khejuri (DOW)	DOW	21.8664	87.9803	300	283	236.0-241.0,275.0-280.0	61.71		2276	7X10-4
16	Khejuri-II	Khejuri (IPz)	IPz	21.8664	87.9803	233	229	226.0-228.0				
17	Khejuri-II block	Khejuri (SPz)	SPz	21.8664	87.9803	60	57	54.0-56.0				
18	Mahishadal	Mahishadal (Pz)	Pz	22.2047	88.0078	298.7	265.5	137.00-143.00,150.80-156.80,183.00-189.00,213.00-222.00,257.50-263.50				
19	Mahishadal II	Kapasaria (DEW)	DEW	22.1294	87.9883	400	349	240.0-252.00,330.00-346.00	28.4		337 (J)	4.9x 10-5
20	Mahishadal II	Kapasaria (DOW)	DOW	22.1294	87.9883	250	234	224.0-234.0				
21	Mahishadal II	Kapasaria (SPz)	SPz	22.1294	87.9883	100	63.9	56.0-62.0				

22	Nandigram-III	Narghat (DPz)	DPz	22.1447	87.8719	300	236	206.00-218.00,226.00-234.00				
23	Nandigram-III	Narghat (SPz)	SPz	22.1447	87.8719	249.55	92	44.00-48.00,62.00-64.00,86.00-90.00				
24	Panskura-I	Kenduara	DEW	22.3825	87.6619	227.08	138.5	59.58-65.07,71.56-65.07,90.76-103.02,108.20-135.18	19.31	13.09		
25	Panskura-I	Kenduara	SEW	22.3825	87.6619	139.57	118.5	43.50-49.50,73.50-83.50,97.50-103.50,106.50-115.50	4.09			
26	Panskura-I	Ratulia	EW	22.4148	87.67	250.07	131.5	38.50-50.50,68-74,82-88,122.50-128.50	8.06	3.81		
27	Panskura-I	Ratulia	OW	22.4148	87.67	135	131	69-75,81-87,123-129		0.55		
28	Panskura-I	Gumai Gajantala	EW	22.3692	87.7522	250	215	140-158,176-182,200-212	18.17	4.98	2673.47	3.56x10-4
29	Panskura-I	Gumai Gajantala	OW	22.3692	87.7522	221.5	208	143-155,174-180,200-206	7.5 (C)	0.43	2649.46	7.33x10-4
30	Sutahata -I	Sutahata (EW)	EW	22.1142	88.0958	295.84	192	134.20-140.20,158.70-164.70,170.00-189.00				
31	Sutahata -I	Sutahata (DEW)	DEW	22.1142	88.0958	400	230	188.0-194.0,220.0-228.0	25.3		789	
32	Sutahata -I	Sutahata (SEW)	SEW	22.1142	88.0958	152		130.0-136.0,144.0-150.0				
33	Sutahata -I	Sutahata (IPz)	IPz	22.1142	88.0958	176		172.0-174.0				
34	Sutahata -I	Sutahata (Pz)	Pz	22.1142	88.0958	295.84	192	134.20-140.20,158.70-164.70,170.00-189.00				
35	Sutahata-I	Barbajitpur (EW)	EW	22.1445	88.0875	466.5						
36	Tamluk-I	Tamluk (SPz)	SPz	22.2947	87.9361	249.55	92	44.00-48.00,62.00-64.00,86.00-90.00				

The deep tube well data of PHED, Govt. of West Bengal has also been collected from the concerned divisions and subdivisions, compiled, analysed, and plotted; Figure 20.2 and table 20.2

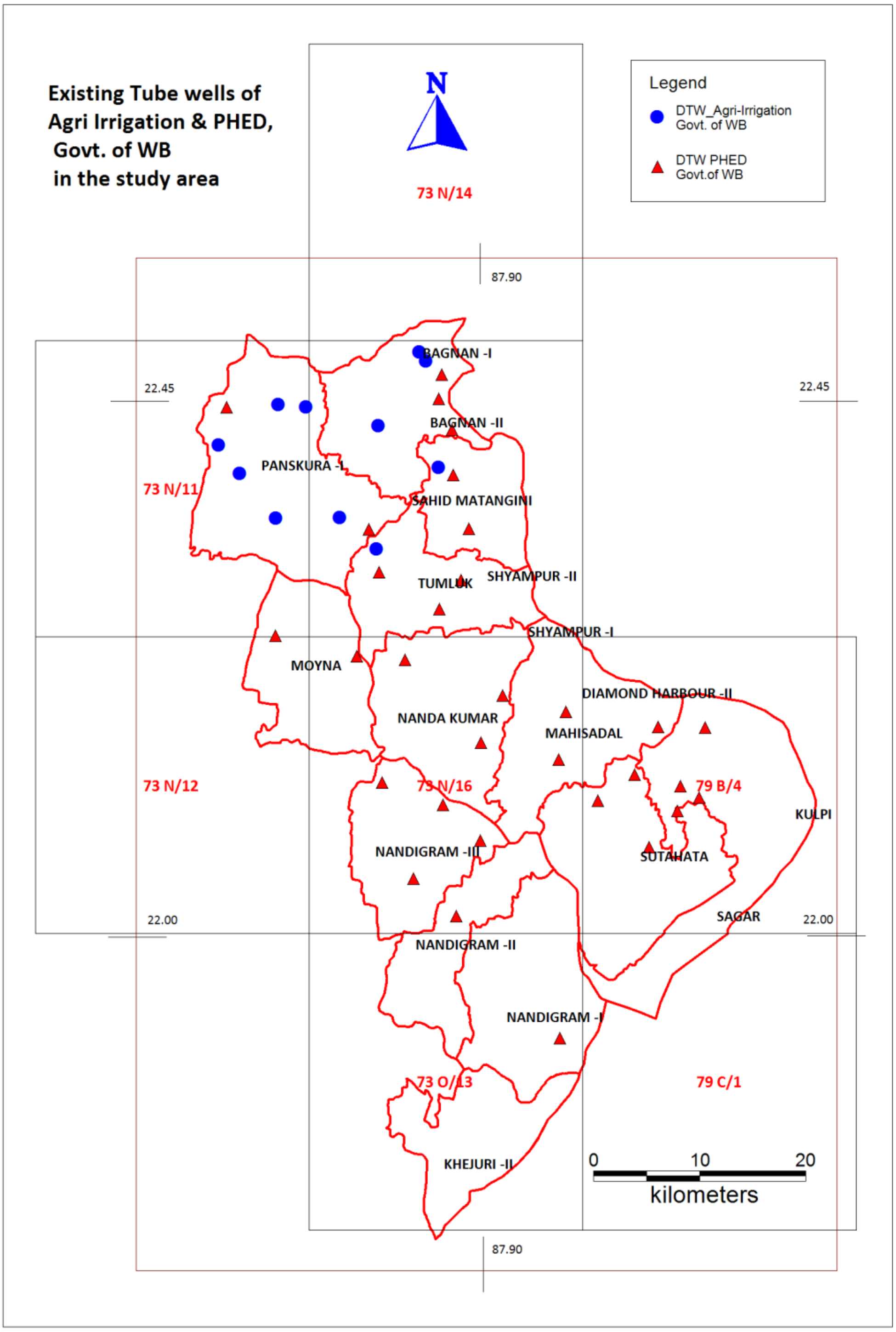


Figure 20.2 Existing Tubewells of State govt dept

Table 20.2 Existing Exploratory/Observation Wells of PHED/AI, Govt. of WB, in the study area

Sl__No_	Location	Block	Well_Type	Latitude	Logitude	Well_Depth__mbgl	Discharge__lps_
1	Muradpur	Chandipur	PHED_DTW	22.0792	87.904	260	20
2	Ersal	Chandipur	PHED_DTW	22.1091	87.8697	280	19
3	Rasikchak	Chandipur	PHED_DTW	22.047	87.8425		
4	Kotbar	Chandipur	PHED_DTW	22.128	87.8141	231	19.2
5	Barsunda	Haldia	PHED_DTW	22.1129	88.0114		17.4
6	Solat	Haldia	PHED_DTW	22.0739	88.0581		21.2
7	Monoharpur	Haldia	PHED_DTW	22.1043	88.0839	294	16.4
8	Dwariberiya	Haldia	PHED_DTW	22.1347	88.0449	283	11.3
9	Asurali Kolaghat	Kolaghat	PHED_DTW	22.4515	87.8661	182	17.7
10	Bathanberia	Kolaghat	PHED_DTW	22.4723	87.8688	180	17.5
11	Mecheda	Kolaghat	PHED_DTW	22.4258	87.8778	192	19.4
12	Bethkundu	Mahisadal	PHED_DTW	22.1748	88.066		16.2
13	Rangibasan TW 2	Mahisadal	PHED_DTW	22.1877	87.9822	265	16.1
14	Kapaseria	Mahisadal	PHED_DTW	22.1474	87.9753	231	
15	Dakhin Mayna	Moyna	PHED_DTW	22.2346	87.791	204	20.9
16	Paramanandapur WSS	Moyna	PHED_DTW	22.2522	87.7166	191	21.7
17	Bargodagodar	Nandakumar	PHED_DTW	22.2316	87.835	210	19.1
18	Khejurberia	Nandakumar	PHED_DTW	22.2016	87.924	222	19
19	Sitalpur (Jalpai)	Nandakumar	PHED_DTW	22.1619	87.9045		17.3
20	Sonachura PH 2	Nandigram I	PHED_DTW	21.9124	87.9763	267	16.1
21	Gholpukur	Nandigram II	PHED_DTW	22.0156	87.8816	229	17.7
22	Gogras Keshab Bar *	Panskura	PHED_DTW	22.3419	87.802	200	20.25
23	Gobindanagar	Panskura	PHED_DTW	22.4445	87.672	180	23.2
24	Mahisda	Sahid Matangini	PHED_DTW	22.3422	87.8935	195	17
25	Chatra	Sahid Matangini	PHED_DTW	22.3874	87.8791	170	15.7
26	Dhenkua	Sutahata	PHED_DTW	22.1744	88.1091	204	17.1
27	Asadtalia	Sutahata	PHED_DTW	22.1154	88.1036	282	15.65
28	Chaitnyapur Zone II (Bhupatinagar)	Sutahata	PHED_DTW	22.125	88.0865	287	16
29	Chapbasan	Tamluk	PHED_DTW	22.299	87.886	223	17.6
30	Simulia	Tamluk	PHED_DTW	22.2745	87.8665	200	17.7
31	Anantapur	Tamluk	PHED_DTW	22.3054	87.8113	180	15.2

	zone II						
32	Khadinan (No 8)	Kolaghat	AI_DTW	22.4831	87.8545	130	
33	Paschim Manika	Kolaghat	AI_DTW	22.4911	87.8483	185	
34	Fakirganj	Panskura	AI_DTW	22.3512	87.7758	189	
35	Ratulia Dolbar	Panskura	AI_DTW	22.4127	87.6649	137	
36	Gotpota	Panskura	AI_DTW	22.3888	87.6845	143	
37	Gopimohanpur	Panskura	AI_DTW	22.4466	87.7197	180	
38	Hatisal	Panskura	AI_DTW	22.4446	87.7447		
39	Deulbrah	Panskura	AI_DTW	22.4287	87.8107	155	
40	Nilmoni Ramchak	Panskura	AI_DTW	22.3506	87.7173	135	
41	Dariala	Sahid Matangini	AI_DTW	22.3934	87.8661	173	
42	Kakurkhana	Tamluk	AI_DTW	22.325	87.8094	150	

20.3 METHODOLOGY FOR ARRIVING AT DATA GAP

20.3.1 Exploratory Data:

The each topo-sheets are considered as spatial scale 5’ x 5’ grids, in which wells of 300 m depth to be constructed in four corner quadrants and with well field in central quadrant. Observation wells may be considered at well field or as per the requirement. The purpose is to determine the aquifer geometry and the aquifer parameters. As per the laid down norms, for two aquifer system 8 wells including EW and OW are required in each toposheet area. The study area comprises 1820 sq km and it encompasses 5 topo-sheets in parts or full. Therefore, more or less 40 well-spaced well distributed representative wells are required in the area to cover each block prudently. The existing exploratory wells data of CGWB has been plotted in the respective toposheets and block map. It is observed that significant gap exists in Kolaghat, Sahid Mmatangini, Moyna , Tamluk, Nandigram I, Nandigram II, Chandipur, Khejuri II and Nandakumar blocks considering the wells of CGWB. The State Govt wells although fills few gaps but seems insufficient to fill the data gap of desired depth and aquifer parameters. **Considering this, additional 32 wells (includes EW and OW) of 300 depths have** been recommended through **outsourcing or in-house** drilling of CGWB to reduce the gap in data rationally. The map of the proposed wells and the list is furnished in Figure 20.3 and table 20.3. The Figure 20.4. shows that the combined map of existing and proposed exploratory well sited in the study area.

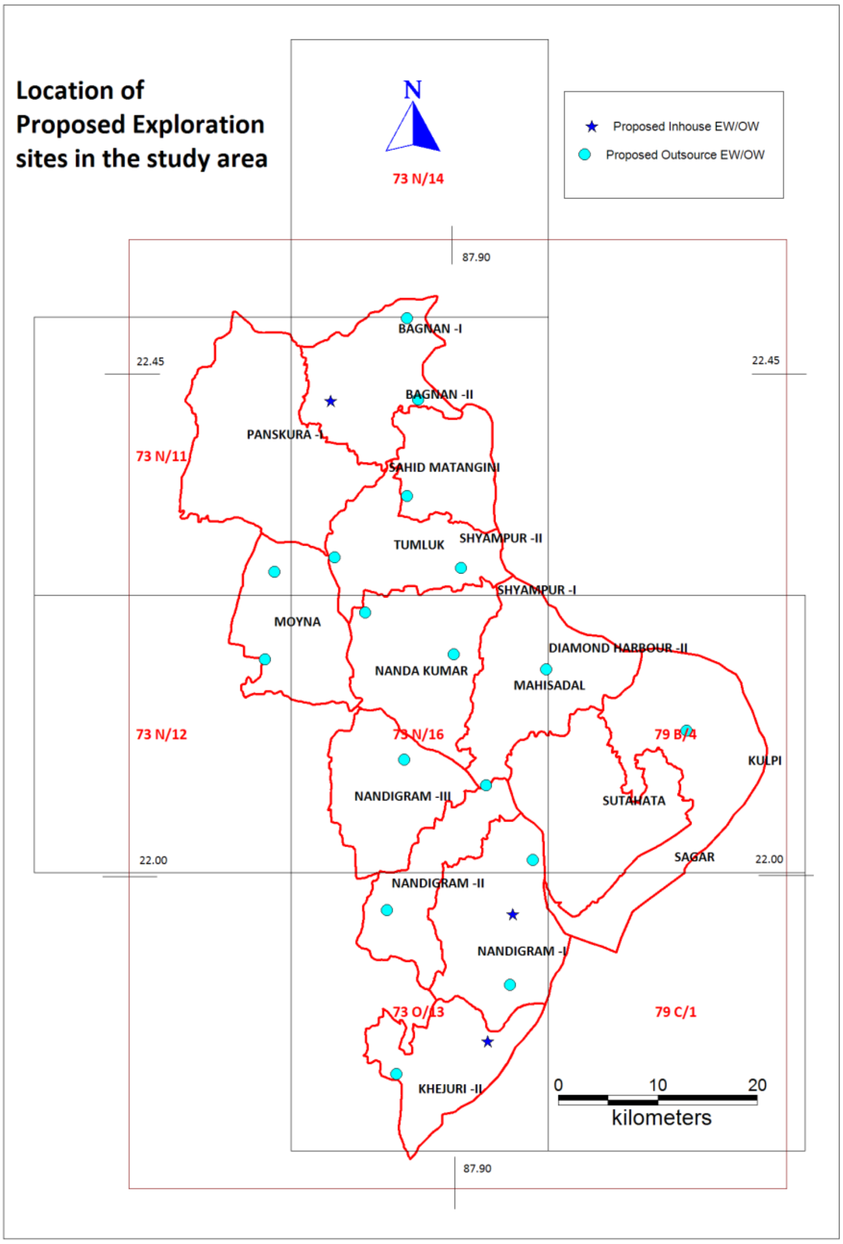


Figure 20.3 Proposed Exploration Sites

Table 20.3 Proposed Outsource and In-house Exploratory well in the study area

Slno	Block	Village_	Proposed for	Latitude	Longitude	Toposheet_ no	Type_ of_We ll	Depth_of _Propose d_well__ m_
1	Kolaghat	Kolaghat	Out source	22.4266	87.8709	73N/15	EW	300
2	Kolaghat	Kolaghat	Out source	22.4266	87.8709	73N/15	OW	300
3	Kolaghat	Machinan	Out source	22.5	87.86	73N/14	EW	300
4	Sahid Matangini	Soyadighi	Out source	22.34	87.86	73N/15	EW	300

5	Tamluk	Tamluk	Out source	22.2754	87.9127	73N/15	EW	300
6	Tamluk	Tamluk	Out source	22.2754	87.9127	73N/15	OW	300
7	Tamluk	Rajnarayan Chak	Out source	22.2845	87.7895	73N/15	EW	300
8	Moyna	Rasikpur	Out source	22.2714	87.7309	73N/11	EW	300
9	Moyna	Rasikpur	Out source	22.2714	87.7309	73N/11	OW	300
10	Moyna	Dubrajpur	Out source	22.1931	87.7221	73N/12	EW	300
11	Nandakumar	Bargoda	Out source	22.2349	87.8197	73N/16	EW	300
12	Nandakumar	Bargoda	Out source	22.2349	87.8197	73N/16	OW	300
13	Nandakumar	Bidysdharpur	Out source	22.1972	87.9058	73N/16	EW	300
14	Mahisadal	Jagannathpur	Out source	22.1841	87.9956	73N/16	EW	300
15	Mahisadal	Jagannathpur	Out source	22.1841	87.9956	73N/16	OW	300
16	Mahisadal	Dinbhumi Chak	Out source	22.0795	87.937	73N/16	EW	300
17	Mahisadal	Dinbhumi Chak	Out source	22.0795	87.937	73N/16	OW	300
18	Nandigram III/ Chandipur	Chandipur	Out source	22.1027	87.8573	73N/16	EW	300
19	Nandigram II	Chingur Dania	Out source	21.9671	87.8403	73O/13	EW	300
20	Nandigram II	Chingur Dania	Out source	21.9671	87.8403	73O/13	OW	300
21	Nandigram I	Nandigram	Out source	22.0125	87.9824	73N/16	EW	300
22	Nandigram I	Sonachura	Out source	21.9	87.96	73O/13	EW	300
23	Nandigram I	Sonachura	Out source	21.9	87.96	73O/13	OW	300
24	Khejuri II	Benichak	Out source	21.82	87.85	73O/13	EW	300
25	Sutahata	Krishna Nagar	Out source	22.1285	88.132	79B/4	EW	300
26	Sutahata	Krishna Nagar	Out source	22.1285	88.132	79B/4	OW	300
27	Kolaghat	Siddha	Inhouse	22.4255	87.7858	73N/15	EW	300
28	Kolaghat	Siddha	Inhouse	22.4255	87.7858	73N/16	OW	300
29	Nandigram I	Maheshpur	Inhouse	21.964	87.9632	73O/13	EW	300
30	Nandigram I	Maheshpur	Inhouse	21.964	87.9632	73O/13	OW	300
31	Khejuri II	Kasaria	Inhouse	21.8497	87.9384	73O/13	EW	300
32	Khejuri II	Kasaria	Inhouse	21.8497	87.9384	73O/13	OW	300

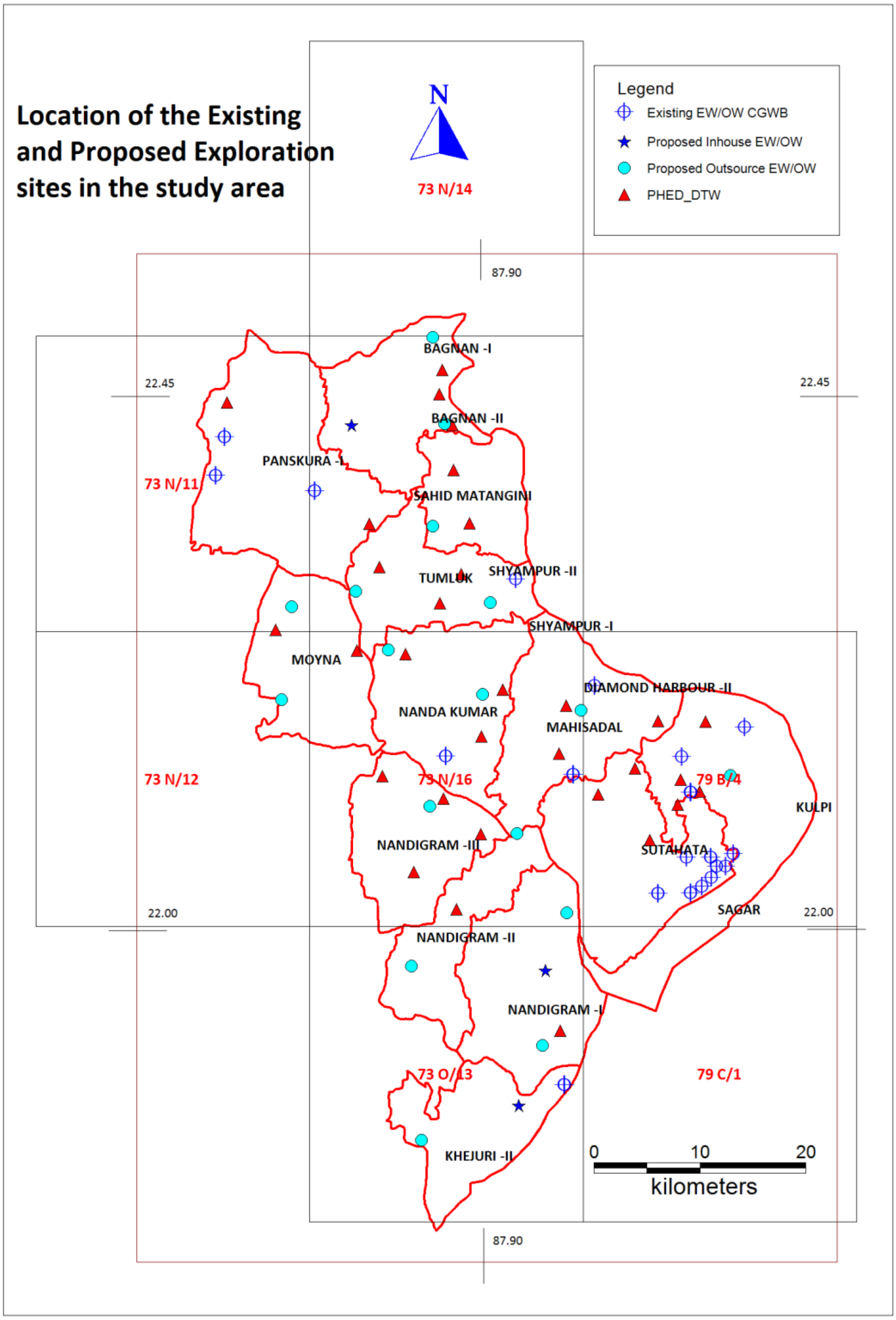


Figure 20.4 Existing & Proposed Exploration sites

20.3.2 Ground Water Monitoring Data:

Considering each topo-sheets as spatial scale -5' x 5' grids, for shallow phreatic aquifer two observation wells are required as per the norms in each quadrant. For 2^{nd} and 3^{rd} aquifer the well-constructed in the Well field and Special Purpose wells may be used as piezometers for GW monitoring. Primarily, it is observed that, the existence of shallow phreatic aquifer in the study area is limited and approximately comprises parts of 2-3 topo sheets or 20 quadrants in parts of Kolaghat, Panskura, Sahid Matangini, khejuri II blocks etc. Therefore, 40 observation wells may be required for phreatic aquifers. On the other hand, considering 4 special purpose wells and 2 wells in well field, one toposheet require 6 wells, thus total 30 wells may be required for 2^{nd} and 3^{rd} aquifers. Therefore, in absence of well field / special purpose well data, **the approximate number of monitoring wells in the study area may be targeted as 70-80 as per the availability ground water monitoring structures in the respective aquifers in the field.** At least two-time monitoring was proposed. Figure 20.5 and table 20.4. depicts the existing wells in different blocks of the study area. The water level monitoring wells are also considered for water quality monitoring stations. At present the water quality data are available for existing NHNS wells only.

20.3.3 Geophysical Data:

2 or 3 Profiling/VES/TEM having 300-meter interpretation depth or as per the feasible spread in the field should be carried out in each of the nine quadrants. Therefore, one topo sheet needs 18-20 no. VES and the area require about 100 VES. However, in the presence of sufficient existing and proposed exploration data the target number of VES may further be reduced.

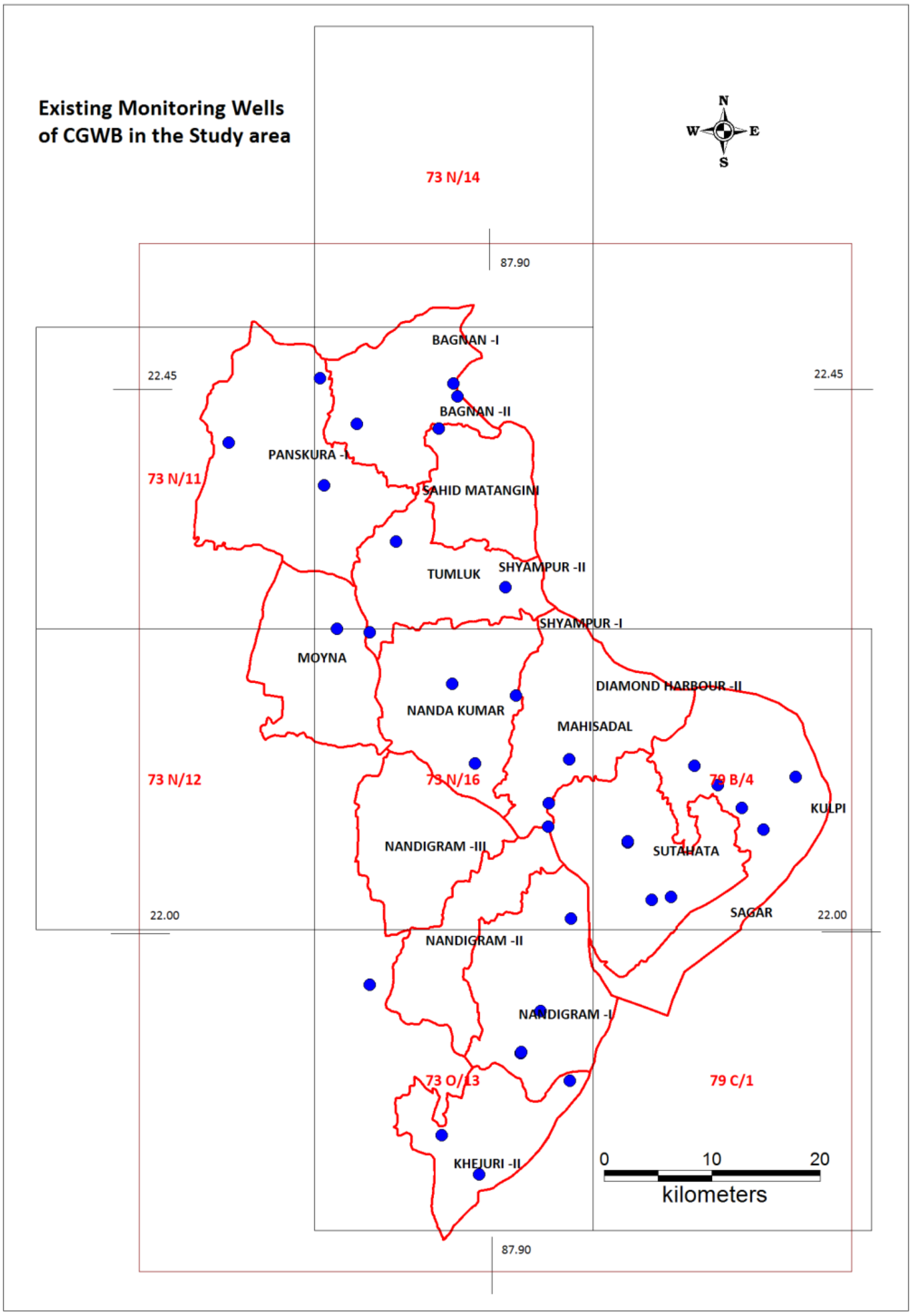


Figure 20.5 Existing Monitoring wells

Table 20.4 Existing monitoring Wells of CGWB

Sl no	Village	Block	Lat	Long	Well type
1	Balughata	Haldia M.	22.0731	88.0283	Pz
2	Basudevpur	Haldia M.	22.0839	88.1500	Pz
3	Haldia Anc.camp	Haldia M.	22.0256	88.0497	Pz
4	Durgachak Pz	Haldia M.	22.1278	88.1792	Pz
5	Haldia Helipad	Haldia M.	22.0281	88.0669	Pz
6	Nijkasba	Khejuri II	21.7975	87.8950	AIDEW
7	Ramchak	Khejuri II	21.8981	87.9322	Mark II
8	Kastala	Khejuri II	22.4917	88.4575	Mark II
9	Heria-i	Khejuri I	21.9550	87.7969	Pz
10	Heria-ii	Khejuri I	21.9550	87.7969	Pz
11	Sher Khan Chak	Khejuri II	21.9331	87.9503	
12	Ram Chak	Khejuri II	21.8992	87.9328	Mark II
13	Khejuri	Khejuri II	21.8750	87.9761	Mark II
14	Chaitanyapur	Mahisadal	22.1367	88.0883	DEW
15	Bagdoba(narghat)	Mahisadal I	22.1389	87.8911	Pz
16	Keshabpur-jalpai	Mahisadal II	22.1056	87.9572	Pz
17	Dakshin Anukhagram	Mayna	22.2506	87.7675	Mark II
18	Mayna	Mayna	22.2478	87.7969	TW
19	Nandakumar	Nandakumar	22.1953	87.9281	Pz
20	Kapasaria Dew	Nandakumar	22.1422	87.9758	DEW
21	Uttar Boyal	Nandigram II	22.0861	87.9569	Mark II
22	Nandigram	Nandigram-I	22.0097	87.9775	TW
23	Diglabad	Panskura	22.4206	87.7853	DW
24	Ratulia	Panskura I	22.4050	87.6703	CGWBOW
25	Gumai	Panskura I	22.3694	87.7558	Pz
26	Jiyakhali	Panskura I	22.4589	87.7519	Pz
27	Kolaghat	Panskura II	22.4436	87.8756	DW
28	Kolaghat	Panskura II	22.4542	87.8717	TW
29	Horkhali	Sutahata	22.6658	88.0089	DW
30	Baluaghata	Sutahata	22.0739	88.0281	Mark II
31	Sutahata Mw	Sutahata I	22.1206	88.1092	Pz
32	Anantapur	Tamluk I	22.3228	87.8206	Pz
33	Tamluk	Tamluk I	22.2850	87.9183	Pz
34	Tamluk Pz-2	Tamluk I	22.2850	87.9183	Pz
35	Ramtarak	Tamluk II	22.2050	87.8708	TW
36	Mecheda	Tamluk II	22.4169	87.8589	Pz