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Aquifer based water security of cities of Eastern India

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Abstract **- The natural resources of Eastern India are still comparatively less exploited. The availability of sustainable water resource in urban environment is a key to development and human health of the Region. 116 Eastern Indian cities with more than 0.1 million population are having adequate water resources. These cities are hotspots for progressive economic development of the country. Water requirement and availability of ground water resources up to present extractable depth of 250 meter has been assessed for 7 capital cities of Eastern India as a case study. The results so obtained clearly indicate availability of ground water is adequate to cope up with the pace of growing population and urbanisation in these cities. Aquifer based water security as sustainable solution of these cities of Eastern India has given the confidence for futuristic development. The result of these studies can be used to predict the aquifer based water security of other Eastern Indian Cities.**

Keywords **- Urban hydrogeology, food and water security, drinking water, aquifer,India**

I. INTRODUCTION

The unprecedented increased rate of human population worldwide with much of these growths taking place in urban areas forced the scientific community and planners internationally to understand the urban ground water issues in depth (Lerner, 1996, Chilton, et al 1997, Chilton, 1999, Howard, 2007). An estimated 1.5 billion people in Asian cities rely on groundwater for their drinking water and other needs (Foster et. al., 2010). The rate of growth of the Asian mega-cities in particular places cause enormous stress on groundwater resources, and leads to the types of over-extraction and pollution that are severely debilitating to these resources (Foster et al., 1998). The urban population of world is expected to reach almost 5 billion, i.e 60% of global population by 2030 (Howard, 2007). More than half of the world's population currently lives in cities; urban dwellers will account for 70 percent of humanity in 2050 (UNESCO,2011). Modern India has witnessed large scale shifting of population from rural tourban areas for their livelihood. Due to migration of rural population mass to the cities, the cities are becoming mega cities and urban centres are enveloping with peri-urban areas to cope up the population explosion. India is a vast country with over 31 percent urban population (Census of India, 2011). The cities are hotspots for progressive economic development of the country. Sustenance of India's economic growth achieved over past two decades needs effective groundwater management (Harsha, 2012). Eastern India comprising of 315 million population, covers the states of Bihar & Jharkhand, Coastal states of Orissa & West Bengal, Seven states of North East (Assam, Meghalaya, Arunachal Pradesh, Manipur, Mizoram, Nagaland and Tripura) and Sikkim. According to the Census of India, 2011, the population in 116 cities of Eastern India is approx 35 million, out of which 110 cities are having > 0.1 million population and 6 cities have over 1.0 million populations. (**Table-1**).

Table-1. Status of Population as per Census of India, 2011

Sl No	State	No of Cities having Population	
		0.1-1.0 million	**>1 million**
1.	Bihar	25	1
2.	Jharkhand	7	3
3.	Orissa	10	0
4.	North Eastern States	9	0
5.	West Bengal	59	2
Total		**110**	**6**

The goal of urban ground water management should be to strike a reasonable balance between maintaining water supply availability and quality, preserving the urban infrastructure and ensure the safe disposal of water. These requirements can be achieved by (1) improving the sustainability of resource exploitation in and around urban centres and (2) more efficient use of available resources. Integrated water resources management strategy adopted in these cities under study has been able to fulfil the growing requirements of water. The Aquifer based water security has brought the requisite sustainability to the supply and also ensures sustainability for near future. The ground water where available is preferred as more secure and safe options over surface water due to its inherent characteristics i.e availability in time and space and protected quality aspects. With the intervention of science more secure and sustainable aquifers has been delineated in these selected cities of eastern India. (**Fig1**).The present paper discusses the case study from 7 capital cities of eastern Indian State to assess contribution of ground water in mitigation of increasing demand of water in cities in general.

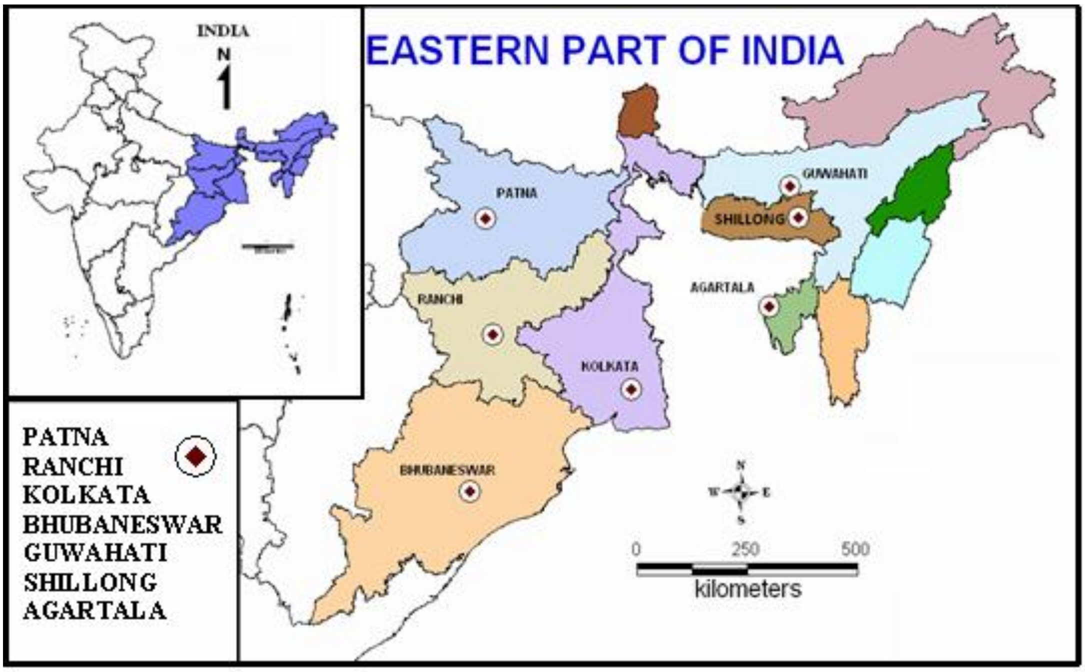


Fig 1 Location map

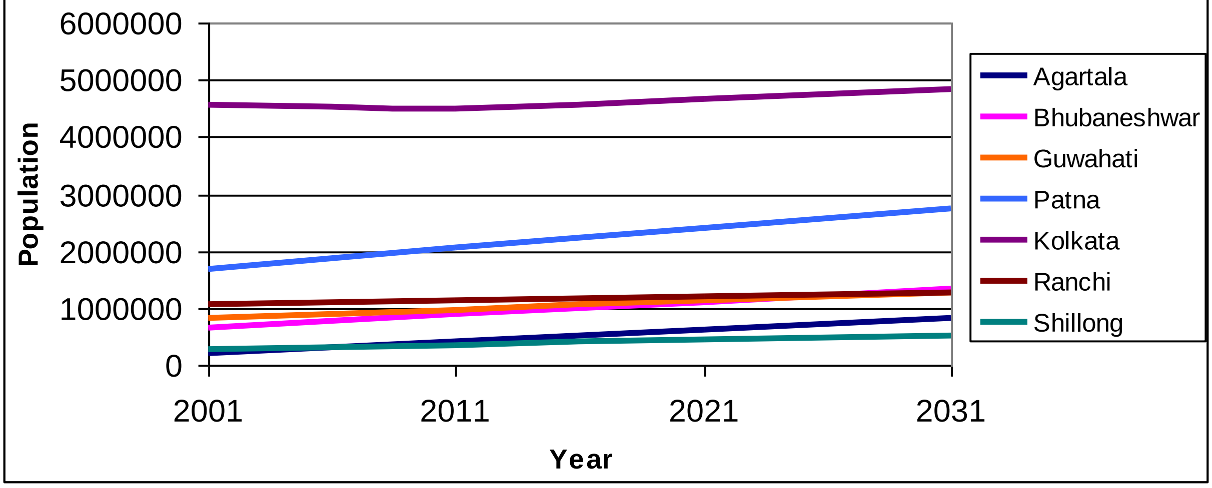
II. METHODOLOGY

The potentiality of ground water towards sustainable solution has been evaluated estimating various parameters. The present total water requirement has been worked out considering 135 litres per capita per day (lpcd) except for Kolkata metropolitan, where 202 litres is taken.The population figures are based on Census of India, 2011 and population growth is projected taking the historical census data to arrive the expected 2031 population. The water level is monitored regionally as well as locally for select cities by the government agencies. The aquifer geometry and its potentiality have been obtained through ground water exploration programme of Central Ground Water Board (CGWB). The ground water resources have been estimated up to 250m depth based on volume of aquifer in the cities and specific yield for the aquifer as determined in exploration. Suitability of groundwater for human consumption has been determined comparing analytical data with BIS standards. The data were collected and compiled for these selected seven cities and analysed to obtain the results.

III. RESULTS

The city taken as case study includes Agartala, Bhubaneswar, Guwahati, Kolkata, Patna, Ranchi and Shillong. These cities are selected being the capital city of these State as representatives of eastern Indian States and its 116 cities, The CGWB has established ground water monitoring mechanism in these cities. The eastern states of India falling mainly under the Ganga and the Brahmaputra basin are blessed with overall better water availability in comparison to rest of India (Jain, 2012, in his table-3).The present water supply and future demand as obtained is based on population data and daily norms. (**Table 2**). The projected population is reflected in the **fig 2.** The aquifer within the city limit has been delineated and its potentiality has been evaluated to know the available ground water resource within the present day maximum exploitable depth of 250 m. The water supply situation in these select cities show that the present contribution of surface water is higher than the ground water in catering the drinking and domestic water needs (table 2), except for Patna, where all water is supplied through ground water abstraction. The future demand of water based on the projected population for 2031 reveals no substantial increase of water demand in four cities Bhubaneswar,Kolkata, Patna and Ranchi. The future additional requirement of water in Agartala, Guwahati and Shillongcan be very well be meet out from available ground water source from the present day exploitable depth of 250m sustainably. Even in these cities additional water requirement for irrigation and industrial need can be fulfilled from aquifer based water supply largely.Hydrogeological setup and ground water quality aspects of these select cities from eastern India taken as case study is presented below

Fig 2. Projection of population in select cities



Hydrogeological Setup

Agartala The semi-consolidated Tipam sandstone of Tertiary age forms the main hydrogeological unit for water supply to the city of Agartala. These sandstones are friable, fine

Table-2. Salient features of availability and water demand for study area

S N	City	Present area of city in km^2	Present Supply of Water in MLD		Projected Demand of water in 2031 MLD	Major Aquifer with thickness up to 250m depth		Availability of ground water resource down to depth of 250m in MCM	Decadal trend of ground water level
			Surface water	Ground water					
1	**Agartala MC**	62.60	31.78	28.18	111	TipamSst	25-55 m	156	Minute Falling trend
2	**Bhubeneshwar UA**	125	154	62	180	AthgarhSst	50-100m	444	Constant
3	**Guwahati UA**	315	98	35	172	Alluvium	40-60 m	998	Constant
4	**Kolkata MC**	187	1161	305	976	Alluvium	30-50m	562	Falling trend
5	**Patna UA**	137	0	493	371	Alluvium	100-140m	1370	Minute Falling trend
6	**Ranchi UA**	257	199	45	173	Gneiss	200m	308	Nearly Constant
7	**Shilong UA**	40	35.16	7.5	71	Quartzite	200m	40	Nearly Constant

UA -Urban agglomerate, MC- Municipal Corporation, MLD- Million litters per day, MCM- Million cubic meter

to medium grained, nearly 200m thick and forms productive aquifers (**Fig 3**). In the city area semi confined aquifers found to occur between 40 and 200 mbgl, which are capable to yield 30-160m^3/hr. Transmissivity value varies from 933-6859 m^2/day for this aquifer (CGWB, 2011). Its piezometric head varies between 3 and 25m bgl. Long term monitoring of the piezometric head in the area depict marginally falling trend(**Fig 4)**. The phreatic aquifer of the city area is in supportive role, having limited potential and is being tapped by individuals through open sanitary wells for household domestic use.

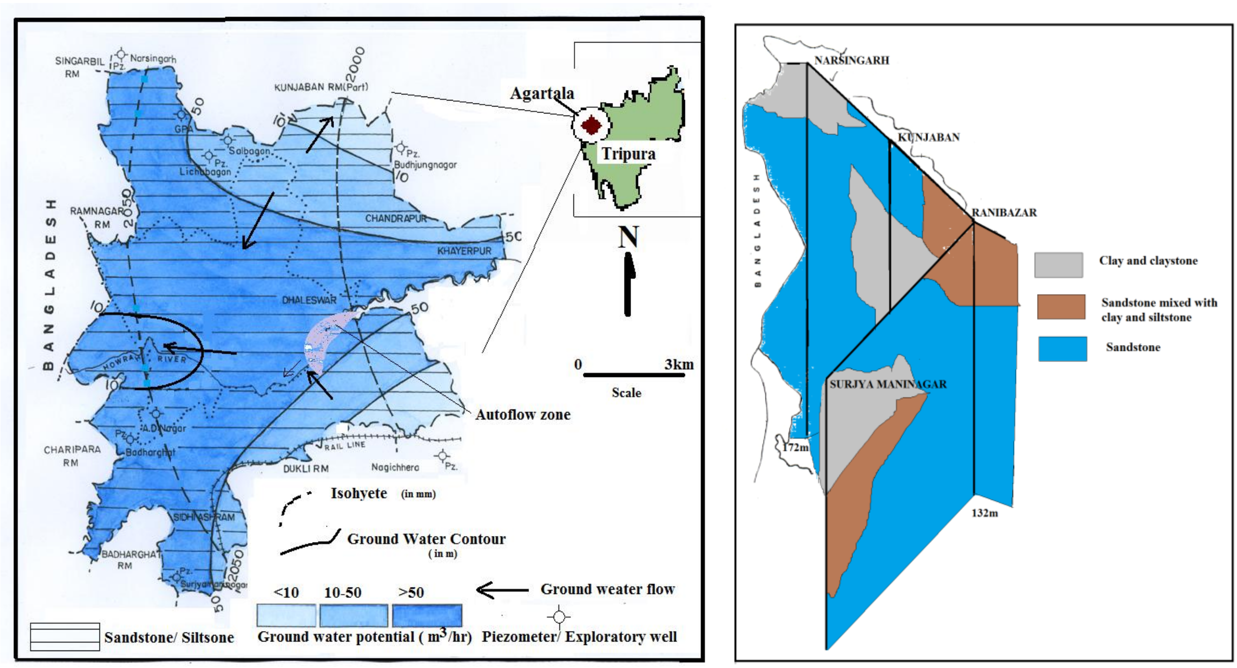


Fig 3 Hydrogeological setup of Agartala

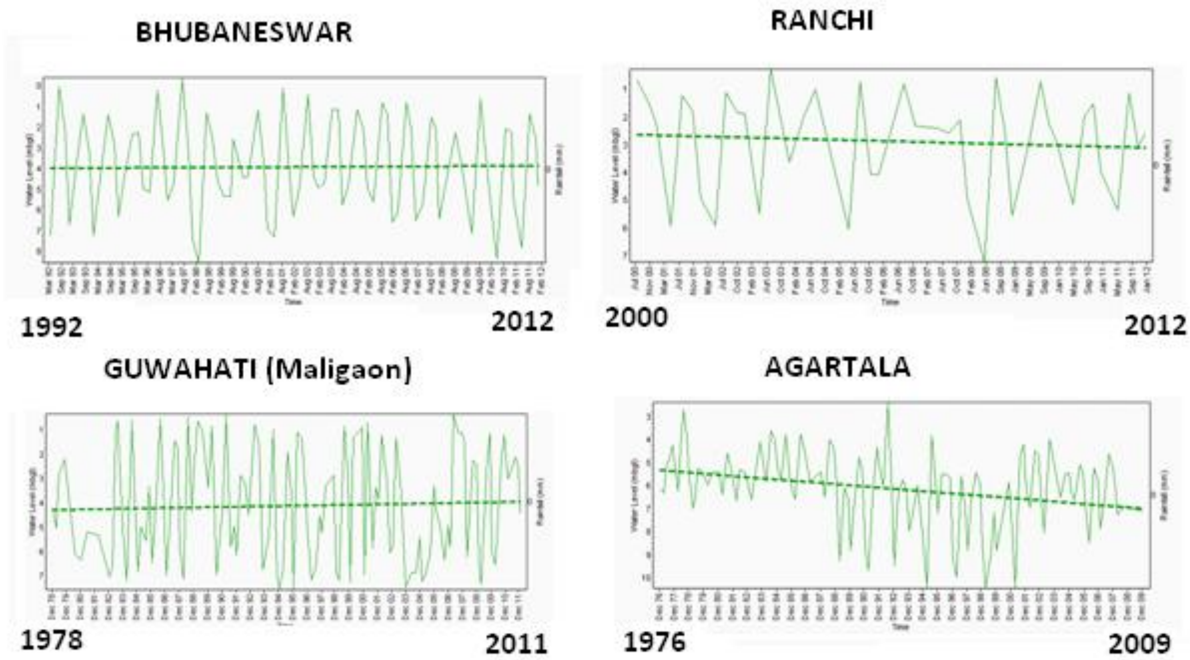


Fig 4.Plot of long term ground water trend

<u>Bhuwaneshwar</u>

The city is mainly underlain by semi consolidated shale-sandstone of Athgarh Formation belonging to the upper Gondwana Group. Laterites and alluvium of quaternary age also occur in small patches in the town. The Athgarh sandstones are fine to coarse grained feldspathic in nature, more than 200 m in thickness. This fractured and friable sandstone down to the depth of 150 m can yield 5-100m^3/hr. Transmissivity value ranges from 15-258 m^2/day for this aquifer. Its piezometric head remains between 2 and 20m bgl. Long term monitoring of the piezometric head in the area depict nearly constant trend(Fig 4). The laterites and alluvium form unconfined aquifers mostly in western and west central parts of the city having limited potential.

<u>Guwahati</u>

The city is underlain by two aquifer system, Quaternary and Precambrian age. The Precambrian formation covers nearly 30% of the city area and largely form isolated highland. The Precambrian aquifer system which constitute fractured Granite-Gneiss, Schist, Amphibolite etc having yield upto 50 m^3/hr within 200m depth range(Fig 5). The Quaternary formations include valley fills, younger alluvium, Older alluvium etc having yield in the range of 12-120m^3/hr within the depth zone of the 200 m(Roy, 2007). The peizometric head varies from 1-36 mgl, however in certain areas auto flow condition occur. Change in Long term water level trend is non-significant.

Kolkata

Kolkata Municipal Corporation (KMC) area is underlain by unconsolidated sediments of quaternary and upper tertiary age deposited under fluvial and sub-marine to marine environments. The principal aquifer in the area occurs in different depth range ,between 40 and 100mbgl in northern part, 60 and 160 mbgl in central part, 180-300mbgl in south western aprt. (Dhiman, 2011).Ground Water in extreme northern , eastern and western part of KMC is brackish with chloride and specific conductance nearly 500mg/l and 2000µs/cm respectively. In western part brackish water aquifer occur down to the depth of 160mgl & 200mbgl. These brackish aquifers are underlain by fresh water aquifer (**Fig6**). The yield of the well range from 90-120m^3/yr. Maximum Transmissivity found upto 2300 m^2/day. Storativity varies from 33x10^{-3} to 20x10^{-5} indicating confined nature of aquifer(Guha, 2009).There is a significant decline in peizometric head. The peizometric trough formed with a core of more than -9m has been expanded in the area and the core has become more than -16 m from 1989-2003. However the present peizometric head remain 7-18m bgl.

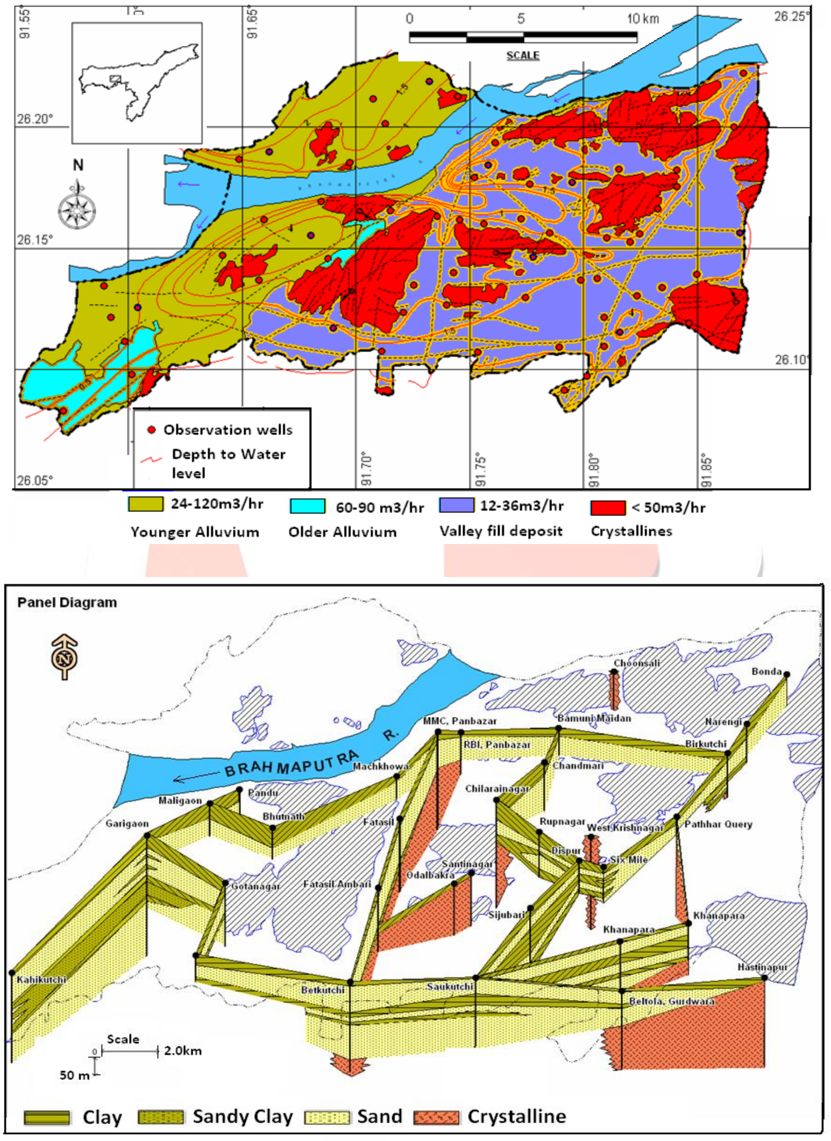


Fig 5Hydrogeological setup of Guwahati

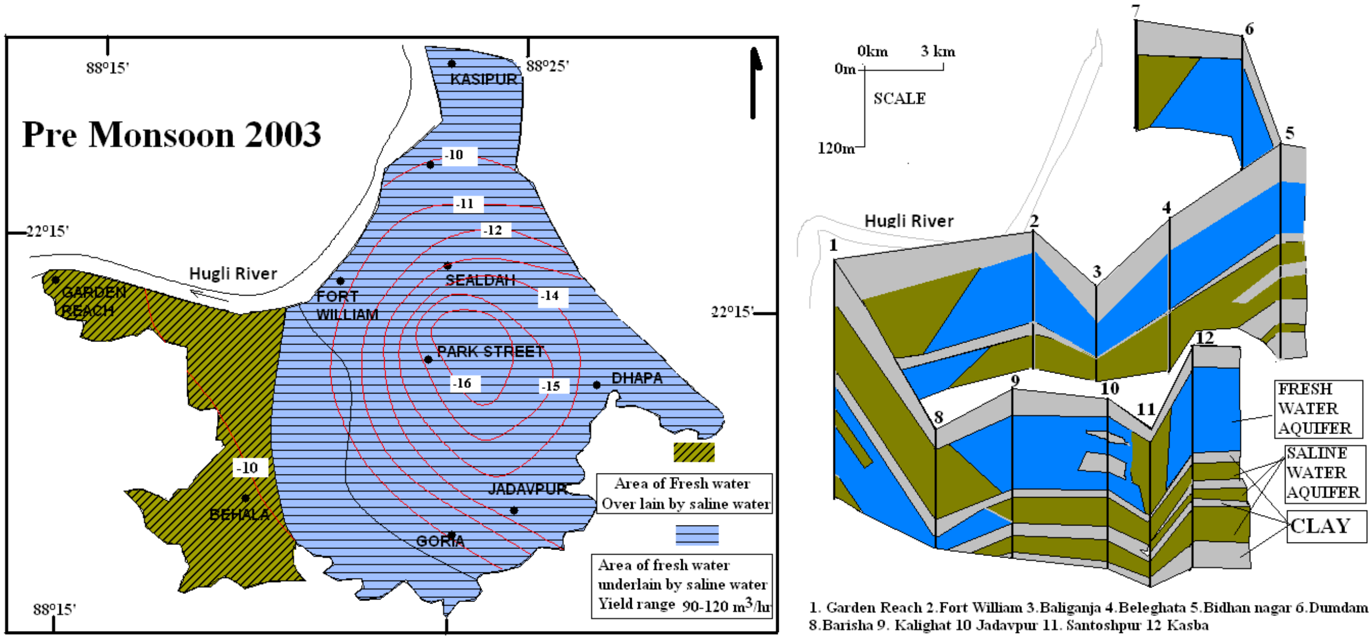


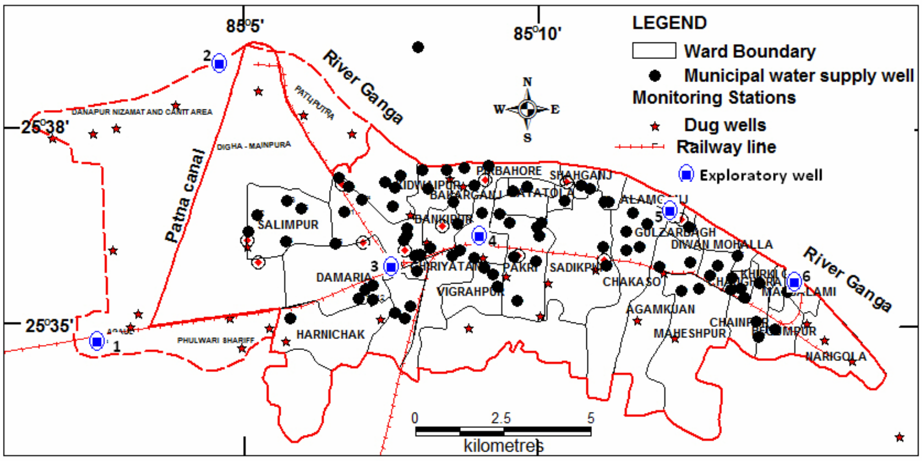
Fig 6. Hydrogeological setup of Kolkata Municipal Corporation area

Patna

Geologically Patna is underlain by quaternary alluvium. Two main group of aquifers exist in the city.Fine to medium sand below the top clay layer constitute the shallow aquifer, while the deeper aquifer having medium to coarse sand occur between 70-200 m. The yield of well range from 60-210 m^3/hr. Transmissivity value varies from 3500-15000 m^2/day. The high potential aquifers can sustain the increased yield on account of future increasing water demand. (**Fig7**). The piezometric head varies from 12-14 m bgl in major part during the pre-monsoon (Dwivedi, et al 2011). Over the year, the ground water regime of shallow aquifers has not shown any major change, however deeper aquifers shows minute declining trend.

Ranchi

The urban area is underlain by Chotanagpur granite-gneiss complex. Ground Water occur unconfined condition in phreatic aquifer and under semi-confined to confined in deeper aquifer. The phreatic aquifer in this formation consists of weathered mantle and saprolite zone. In general, the thickness of weathered zone varies between 5.5- 25 m, however in localized patches it is > 35 m. The potential fractures were delineated between 70-150 m depth and having yield 1-25 m^3/hr. Transmissivity ranges from 2-80 m^2/day. Long term monitoring of the piezometric head in the area depict nearly constant trend.



1 Khagaul 2 Danapur 3. Mithapur 4. Kadamkuan 5. Khajekalan 6. Pirdamaria

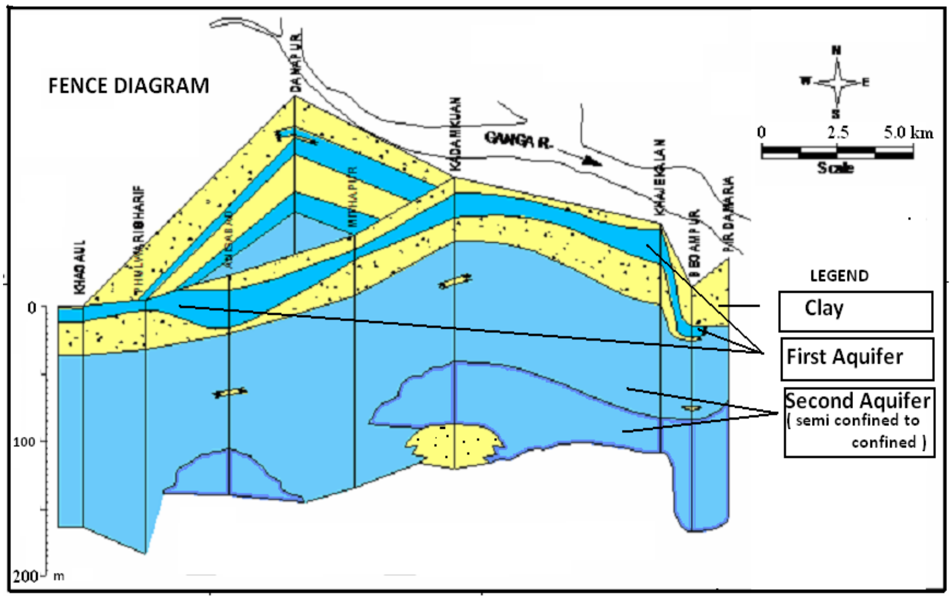


Fig 7Hydrogeological setup of Patna

<u>Shillong</u>Geologically Shillongcity is underlain by Shillong Group of rocks consisting of quartzite &phyllites. Ground water occur under water table condition in weathered and fractured zone of Precambrian quarzites, while semi-confined to confined condition in joints, fractures in the depth of 60-180m. Yield of bore wells range from 1-20m^3/hr. Artesian wells having free flowing discharge of 0.13 -3.6 m^3/hr. Depth to water level varies from 5-10m bgl while the piezometric head remains between 2.0 and 17.0mbgl.Long term monitoring of the piezometric head in the area depict nearly constant trend. Springs play an important role in domestic water supply having discharge in the range of 0.3-7.0m^3/hr

Ground water quality aspects

Ground water quality of these selected cities by and large is good and not posing any serious threat whatsoever to the water supply agencies (CGWB,2010 and 2011). The hydrochemicaldata of ground water from these cities are presented in **Table-3** and is compared with the BIS standards. Patna and Kolkata urban area having all along thick clay layer beneath these cities at shallow depth(fig 6 and 7), protecting the principal aquifers from anthropogenic pollution,the aquifers which is under use provides safe drinking water source. The other cities like Agartala, Bhuwaneshwar and Guwahati situated on porous aquifer having potable water at desirable depth. However higher concentration of Iron in ground water tapped from semi-confined to confined aquifer is the real challenge at many sporadic places over these cities. The cities on hard rock suchas Ranchi and Shillong are having fractured aquifer with suitable quality of water,occasional higher iron incidence is noted. Higher Fluoride in deeper granular zone has been reported by Central Ground Water Board during its exploratory drilling, ranging 1.5 to
4.48 ppm in Guwahati (Roy,2007). Higher Arsenic contamination has been reported from few

City	EC	pH	Ca	Mg	Na	K	Cl	F	NO_3	HCO_3	SO_4	Fe	Remarks
	□ s/c m		---in mg/l---										

Agartala	70-230	6.9-8	31-84	0.8-7.3	5-18	-	10-25	-	-	20-150	-	0.1-12.38	No significant issue
Guwahati	115-1650	6.70-8.09	6-92	1.2-52	-	-	7-213	0.02-0.94	15-56	12-366	1-72	0.02-7.23	Deeper aquifer with high F
Shillong	17-280	6.4-8.1	1.6-22	0.49-9	-	-	2-25	-	-	4.9-103	-	0.02-1.3	No significant issue
Ranchi	162-1168	7-8	26-50	3.6-13	6-21	2-6.6	14.2-192	-	-	109-223	-	-	Sporadic high Fe problem
Patna	295-1232	-	12-56	13-34	23-127	1.8-3.5	41-142	-	-	140-232	-	-	Dug well zone having higher EC, and NO_3 & microbial pollution
Kolkata	331-2500	6.9-8.3	8-150	9.7-523	5.2-488	<1-10	32-789	0.01-1.08	1-14	150-671	<1-78	0.1-7.67	As-0.054-0.71
Bhubaneswar	70-350	7.7-8.1	8-28	1.22-7.29	5-36	3-10	7-74	0.2-0.47	-	31-79	3-62	-	Sporadic high Fe problem
BIS (ISO10500:1992) Permissible limits	2000 TDS	6.5-8.5	200	10\0	-	-	1000	1.5	100		400	1.0	Arsenic 0.05

Table 3 The hydrochemicaldata of ground water from seven cities

places in shallow aquifer zone of KMC ranging from 0.054-.071 ppm (Dhiman, 2011), however the principal aquifer from where drinking water is being extracted is free from Arsenic contaminations. Central Ground Water Board through specially designed cement seal wells (Mishra and Nag, 2009) has established arsenic free ground water supply. Utmost care has to be taken to protect the deeper aquifer from the contamination of arsenic from shallow zone through specialised well designing. Proper ground water regulation in this regard has to be initiated at state level to protect the deeper arsenic free zone from contamination due to faulty construction of deep tube wells in KMC area. State govt agencies from sub-urban areas of Danapur block of Patna have reported sporadic high arsenic values, which need further investigations.

IV. DISCUSSIONS

The results as obtained clearly indicate availability of ground water to cope up with the pace of growing population and urbanisation in these cities (Table 2). The constant to nearly constant long term ground water trend (except Kolkata) in these cities reflect the low stress conditions on aquifer. Ground Water quality barring Kolkata is good and potable with sporadic high iron and fluoride concentration. However patches of anthropogenic contamination have been observed in the shallow aquifer, which are not being in use for drinking purposes. In Kolkata the fresh water aquifers are occurring in between brackish aquifer and are constrained due to presence of geogenic Arsenic contamination. The aquifer based water security has provided additional sustainable source of safe drinking water. If the proportion of ground water abstraction remain nearly same as today then the present ground water resource is adequate for long term basis. Higher abstraction proportion than present also sustain fairly long with the help of regional ground water flow pattern and recharge condition. However adequate managed aquifer recharge projects can enhance the sustainability. The limited fresh ground water resource of Kolkata city can sustain the present draft ratio through adequate management strategies. For additional requirement the deeper aquifer to be tapped beyond 250 m depth as in the Bengal basin the sediment thickness is over 5000 m .The deeper arsenic free aquifer at KMC has to be protected from arsenic contaminated shallow aquifer through proper ground water regulation. The faulty construction of tube wells should not contaminate the deeper aquifer connecting to the shallower aquifer through leakage.

With increase of population, the city area in these cities are likely to increase (except KMC) in future, which can provide additional ground water recourse within the city area as shown in his study by Mukherjee (2007). With 10% increase of city area, ground water availability also likely to increase by 10%. The density of population thus reduces to improve the per capita water availability.Based on above discussions it can be stated that aquifer based water security for other eastern Indian cities can also be found sustainable because of their similarities in geographical and geological scenario, socio-economic conditions and population growth trend in near future.

CONCLUSION

The case study of seven capital cities from eastern India clearly indicatethat the ground water availability is adequate to cope up with the pace of growing population and urbanisation in these cities in near future. The quality of ground water of principal aquifer within these cities is good and portable in general, which also support the availability. Aquifer based water security as sustainable solution of these cities of the eastern India has given the confidence for futuristic development. Proper ground water regulation has been recommended for the Kolkata metropolitan to protect the deeper arsenic free aquifer from contamination.The result of these studies can be reproduced to predict the aquifer based water security of other eastern Indian cities reliably.

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