# GROUNDWATER BUDGETING OF PANDUA BLOCK OF HUGLI DISTRICT, WEST BENGAL

**Arijit Majumder and Dr. Lakshmi Sivaramakrishnan**

*Department of Geography, The University of Burdwan, Burdwan, West Bengal, India.*

*Email: arijit.majumder83@gmail.com, lakshmi.bu@gmail.com*

***Abstract: Rapid rise of population has created a huge demand for water in agriculture, industrial and domestic sectors in India especially in states like West Bengal. The annual availability of water from rainfall in West Bengal is 85.23 bcm (billion cubic metres) while consumption in different sectors altogether amounted to 106.18 bcm in the year 2001. Thus the gap is supplemented either by transboundary water or by over exploitation of groundwater. The increase in number of tubewells for irrigation purposes in West Bengal shows the dependency of irrigation on groundwater which has increased from 236432 tubewells in 1980-81 to 545956 tubewells in 1990-91. According to Census 2001 91.4 percent of rural households and 41.2percent of urban households in West Bengal depend on groundwater for their drinking water supply. Groundwater in West Bengal is over-exploited and out of 341 blocks, 38 blocks are under critical or semi-critical condition. The present study deals with the 'Groundwater Budgeting' of Pandua block of Hugli district which is a semi-critical block of West Bengal. The block lies in complete alluvium area which is generally considered as groundwater potential zone of a region. Excessive Draft of groundwater over natural recharge in an area leads to loss of groundwater storage in that area over the period of time. The present study aims at computing the groundwater budget in Pandua block of Hugli district, West Bengal as there is a continuous fall of static water level for the last 40 years. The annual recharge of Pandua block of Hugli district has been calculated based on the product of specific yield, static water level fluctuation (pre-monsoon to post-monsoon) and area of the block for the year 2008.***

***Panel diagram of the lithologs of the area helps to understand the proper lithology of the area, aquifer characteristics and the dynamics of groundwater. The fluctuated lengths of the static water level have been superimposed on the 65 available lithologs and are differentiated in accordance to their texture viz: clay, sandyclay, fine sand, medium sand and coarse sand. The specific yields of the respective textures are equated with corresponding differentiated length of static water level fluctuation and the area of the block to estimate the recharge of the block. Draft of groundwater has been calculated based on primary data collected from field. Thus the groundwater budget of the alluvium area has been computed for the year 2008. The paper aims to unfold the groundwater budget of the block so as to adopt proper planning and take necessary steps for making the area sustainable with respect to groundwater.***

***Keywords: static water level, semi-critical block, specific yield, stage of groundwater development.***

## 1.Introduction

Groundwater is replenishable but a finite resource[4]. India is the biggest user of groundwater in agriculture in the world and it has been on rise since 1970's[11]. Depletion of groundwater storage is the first indicator of water scarcity[12]. Hence the quantitative analysis of groundwater of vulnerable areas helps to find out the real cause of groundwater depletion and its consequences. The cause and effect relationship ultimately leads to adopt the required management techniques and decisions to be implemented. In West Bengal the annual availability of water from rainfall in West Bengal is 85.23 bcm (billion cubic metres) while consumption in different sectors altogether amounted to 106.18 bcm in the year 2001 [13]. The gap is supplemented either by transboundary water or by over exploitation of groundwater [13].

### 1.1 Selection of the Area Under Study

There are 341 blocks in West Bengal, out of which 38 blocks are categorized as critical and semi-critical block [13]. A critical block is one where the stage of groundwater development is (90-100)% and there is pre-monsoon and post-monsoon fall of static water level[4]. A semi-critical block is defined as the block where the stage of groundwater development is (70-90)% and there is either a pre-monsoon or post-monsoon fall of static water level[4]. Pandua block of Hugli district is a semi-critical block where there is either a pre-monsoon or post- monsoon fall of static water level according to Central Ground Water Board[13]. The latitudinal extension of the area is 23d00'N – 23d10'N while the longitudinal extension is 88d10'E – 88d24'E. The area of the block is 276.4 square kilometers [3]. The area lies within an interfluve where the river Hugli flows on the east and the river Damodar on the west. The area is a meander flood plain which represents the newer alluvium [9]. The newer alluvium or the Holocene deposition is characteristically unoxidised and consists of sand, silt and clay mainly deposited in fluvial settings [1]. Hence this area is considered as highly potential for recharge. The calculation of Water-Balance by Thornthwaite & Mather method shows that the block is water excess region [8]. Thus this particular block has been selected for the study due to the irony of the following facts:

1. According to water balance calculations the block belongs to a water excess category.
2. It is composed of unconsolidated Quaternary alluvium and hence considered highly conducive to recharge.
3. The block is a semi-critical block according to CGWB.

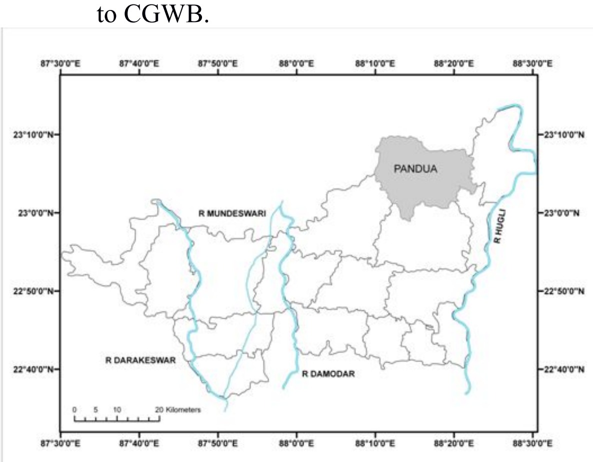


Fig 1: Location of Pandua block in Hugli district (prepared on the basis of the map of Census of Hugli district, 1961).

## 2. **Materials and Methods**:

The present study depends mainly on primary data collected from field, secondary data and maps obtained from different sources which are given below:

4. The fall of static water level is more than 10 metres in last 40 years [7].

Thus the research question arises regarding the fall of static water level of this particular block. A LISS-IV image of the block has been classified and according to the report of classification it is seen that 89% of the area is under agriculture or agricultural fallow. Hence a relevant question has been adopted for the present study.

Research Question: The fall of static water level in Pandua block is due to drafting of groundwater for irrigation within the block.

Objective: Computation of the groundwater budget of Pandua block of Hugli district in the year 2007.

1. Static water level data has been collected from State Water Investigation Directorate, West Bengal.
2. Borehole data has been obtained from Agri-Irrigation Department, Hugli, West Bengal.
3. Block map of Pandua has been obtained from 1961 census.
4. Shuttle Radar Topographic Mission image has been downloaded from Global Land Cover Facility website.
5. Primary data has been collected from field to calculate the draft due to irrigation within the block.

Borehole data collected from Agri-Irrigation Department has been used to study the lithology of the area

The Panel diagram has been prepared in accordance to the running depth of the soil texture and based on the reduced level of the vector points. The panel diagram has been shown to have a clear idea of the lithology of the study area.

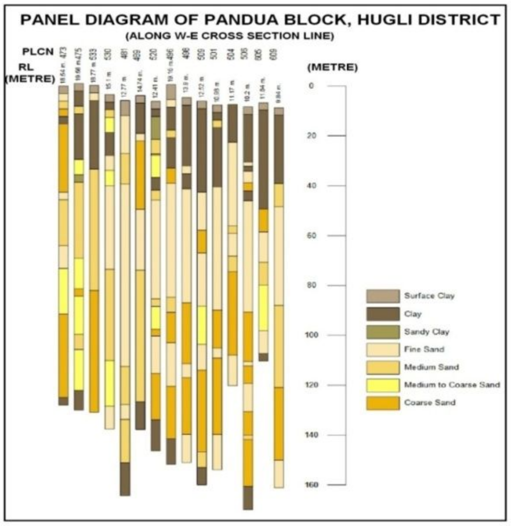


Fig 2: Panel diagram showing the lithology of Pandua block (Prepared by authors based on the data provided by Agri-Irrigation department, Hugli)

Change of Storage of Groundwater in 2007

Change of storage of groundwater of an area is calculated on the basis of the following formula:

d(STORAGE) =Static Water Level Fluctuation * Area * Specific Yield (rchat)

For the preceding formula, the static water level is measured as the difference in the post-monsoon and pre-monsoon static water level which is measured in the month of November and April respectively. Hence the fluctuation is measured as the difference in the static water level in the month of November 2007 and April 2007 respectively.

The area of the block is a constant and is equal to 276.4 sqkm.

The specific yield of a soil sample is the volume of water that, after saturation, can be drained by gravity to its own volume [10]. Thus the specific yield of a sample is a function of its texture. The static water level fluctuation length of the 65 vertical column has been taken and is differentiated according to their specific yield. In 2007 the pre-monsoon to post-monsoon static water level fluctuation is 7.61 metres. The pre-monsoon level is 19.95 metres below ground level while the post-monsoon level is 12.34 metres below ground level. Hence the specific yield of the different textures of this fluctuation measure has been considered. The differentiated fluctuation lengths are multiplied with their respective specific yield and are summed up for each lithologs to get the weighted mean [7]. The summation obtained from all the 65 litholog datasets are then computed to get the mean of the weighted mean. This mean value of the product of fluctuation and specific yield is the multiplied by the area of the block to obtain the change in storage in the year 2007. The values of specific yield of different textures are tabulated as shown in table1.

Table 1**: Values of Average Specific Yield of Different Materials**

| Material | Average Specific Yield (%) |
|---|---|
| Clay | 2 |
| Sandy Clay | 7 |
| Fine Sand | 21 |
| Medium Sand | 26 |
| Coarse Sand | 27 |

Source: Johnson, 1967

**3. Results and Discussions**:

Determination of Groundwater Recharge: For determining the groundwater recharge within Pandua block the differentiated lengths of the lithologs have then been multiplied by specific yield of their respective texture. Table 2 represents the calculated values of the weighted mean of the product of differentiated length and specific yield.

Table 2: **Differentiated Length of Fluctuation of Static Water Level**

| SL | TEXTURE | d L1 | TEXTURE | d L2 | TEXTURE | d L3 | TEXTURE | d L4 | TEXTURE | d L5 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Clay | 2.91 | Sandy Clay | 4.7 | | | | | | |
| 2 | Clay | 2.9 | Coarse Sand | 3.05 | Clay | 1.66 | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Clay | 7.61 | | | | | | | | |
| 4 | Clay | 7.61 | | | | | | | | |
| 5 | Clay | 2.9 | Fine Sand | 4.71 | | | | | | |
| 6 | Coarse Sand | 7.61 | | | | | | | | |
| 7 | Clay | 4.42 | Fine Sand | 3.19 | | | | | | |
| 8 | Clay | 7.61 | | | | | | | | |
| 9 | Clay | | Fine Sand | 0.48 | Sandy Clay | 2.42 | Clay | 4.71 | | |
| 10 | Sandy Clay | 2.9 | Fine Sand | 4.71 | | | | | | |
| 11 | Clay | 5.95 | Fine Sand | 1.66 | | | | | | |
| 12 | Clay | 7.61 | | | | | | | | |
| 13 | Medium Sand | | Clay | 7.61 | | | | | | |
| 14 | Clay | 7.61 | | | | | | | | |
| 15 | Clay | 7.61 | | | | | | | | |
| 16 | Clay | 7.61 | | | | | | | | |
| 17 | Clay | 2.9 | Sandy Clay | 4.71 | | | | | | |
| 18 | Clay | 7.61 | | | | | | | | |
| 19 | Clay | 7.61 | | | | | | | | |
| 20 | Clay | 7.61 | | | | | | | | |
| 21 | Coarse Sand | | Clay | 5.95 | Sandy Clay | 1.66 | | | | |
| 22 | Clay | 2.9 | Medium Sand | 4.71 | | | | | | |
| 23 | Clay | | Sandy Clay | 2.9 | Coarse Sand | 3.05 | Clay | 1.66 | | |
| 24 | Sandy Clay | | Clay | 7.61 | | | | | | |
| 25 | Fine Sand | | Clay | 7.61 | | | | | | |
| 26 | Coarse Sand | | Clay | 7.61 | | | | | | |
| 27 | Fine Sand | | Clay | 5.95 | Medium Sand | 1.66 | | | | |
| 28 | Clay | 5.95 | Fine Sand | 1.66 | | | | | | |
| 29 | Clay | 7.61 | | | | | | | | |
| 30 | Clay | 5.95 | Coarse Sand | 1.66 | | | | | | |
| 31 | Clay | 7.61 | | | | | | | | |
| 32 | Clay | 7.61 | | | | | | | | |
| 33 | Clay | | Medium Sand | | Clay | 7.61 | | | | |
| 34 | Medium Sand | | Clay | 7.61 | | | | | | |
| 35 | Clay | 7.61 | | | | | | | | |
| 36 | Clay | 7.61 | | | | | | | | |
| 37 | Fine Sand | | Coarse Sand | 7.61 | | | | | | |
| 38 | Clay | 7.61 | | | | | | | | |
| 39 | Clay | | Fine Sand | | Clay | 7.61 | | | | |
| 40 | Clay | 2.91 | Fine Sand | 4.7 | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 41 | Clay | | Fine Sand | | Clay | 2.91 | Coarse Sand | 4.7 | | |
| 42 | Clay | | Coarse Sand | 2.9 | Clay | 4.71 | | | | |
| 43 | Coarse Sand | | Fine Sand | | Medium Sand | 2.9 | Coarse Sand | 3.35 | Clay | 1.36 |
| 44 | Clay | 2.9 | Fine Sand | 3.05 | Coarse Sand | 1.66 | | | | |
| 45 | Clay | 5.95 | Medium Sand | 1.66 | | | | | | |
| 46 | Clay | 7.61 | | | | | | | | |
| 47 | Clay | 7.61 | | | | | | | | |
| 48 | Clay | 5.95 | Medium Sand | 1.66 | | | | | | |
| 49 | Clay | | Medium Sand | 7.61 | | | | | | |
| 50 | Clay | 7.61 | | | | | | | | |
| 51 | Clay | | Medium Sand | | Clay | 7.61 | | | | |
| 52 | Clay | 2.9 | Fine Sand | 4.71 | | | | | | |
| 53 | Medium Sand | | Coarse Sand | 2.9 | Clay | 4.71 | | | | |
| 54 | Clay | 2.9 | Coarse Sand | 4.71 | | | | | | |
| 55 | Medium Sand | | Coarse Sand | | Clay | 2.9 | Coarse Sand | 4.71 | | |
| 56 | Sandy Clay | 3.2 | Medium Sand | 2.44 | Clay | 1.97 | | | | |
| 57 | Clay | 7.61 | | | | | | | | |
| 58 | Fine Sand | 7.61 | | | | | | | | |
| 59 | Clay | 2.9 | Medium Sand | 4.71 | | | | | | |
| 60 | Fine Sand | 2.9 | Clay | 4.71 | | | | | | |
| 61 | Clay | 2.9 | Sandy Clay | 4.71 | | | | | | |
| 62 | Fine Sand | | Coarse Sand | 2.9 | Clay | 4.71 | | | | |
| 63 | Clay | 7.61 | | | | | | | | |
| 64 | Sandy Clay | | Coarse Sand | 7.61 | | | | | | |
| 65 | Medium Sand | | Coarse Sand | 2.9 | Medium Sand | 4.71 | | | | |

Source: Calculated by authors.

Substituting the values of specific yield in place of the textural classes and consequent computation of the table the change in storage of 2007 pre-monsoon to post-monsoon is obtained. The mean of the weighted mean is multiplied with the area of the block to find out the recharge of Pandua block which amounts to 18117.24 hectare-metre (ham).

**3.1 Groundwater Draft**:

Groundwater draft in this area is mainly done due to irrigation within this block. Drafting of groundwater is also done for domestic water supply by Public Health Engineering (PHE) department. There are basically two types of tubewells for supplying water for irrigation purpose viz: the shallow tubewells locally called as ‘Mini’ which are operated by the private mini-owners and the Deep tubewells operated by the Agri-Irrigation department, GoWB. Therefore groundwater drafting has to calculated separately for the shallow tubewells, deep tubewells and domestic draft.

### 3.2 Computation of Groundwater Draft by the Shallow tubewells:

There are 1482 shallow tubewells within the block [5] which is the largest abstraction unit of groundwater irrigation. Primary field survey has been made to find out the amount of water drafted. The main crop types of this area are rice and potato. The rice is cultivated twice a year, once in the rainy season which is known as Aman and in the late winter known as Boro. The data of the mean hours/acre/season of groundwater drafting has been collected from primary field survey. Table 3 represents the groundwater drafting time of different crops cultivated in different times of the year.

The data for the total area cultivated for different crops are available in MI census 2012. Thus the total running hour for each type of crops can be calculated. The discharge of the shallow tubewells has been measured at the field. All the 'Mini's or the shallow tubewells have a 5 horsepower motor for drawing the water from underground to the surface. The mean discharge measured at field is 38.43m3/hr. Thus the calculation of total groundwater draft by shallow tubewells is measured and table 3 represents the total groundwater draft by shallow tubewells.

Table 3: **Calculation of Total Groundwater Draft by Shallow Tubewells**

| Type of Crop | AMAN | POTATO | BORO |
|---|---|---|---|
| Running hour/hectare (hour) | 64.86 | 77.90 | 369.94 |
| Area Cultivated (hectare) | 5020.14 | 3017.69 | 3876.88 |
| Total Running hour (hour) | 325619.75 | 235087.78 | 1434243.67 |
| Discharge (cubicmetre/hour) | 38.43 | 38.43 | 38.43 |
| Total Draft (hectare-metre) | 1251.35 | 903.44 | 5511.79 |

Source: Calculated by authors based on field survey.

### 3.3 Computation of Draft due to Irrigation supplied by Deep Tubewells:

Data of running hour of different tubewells for supplying water for irrigation in this block has been collected. The tubewells are basically divided into four categories viz: Heavy duty tubewells, Medium duty tubewells, Low duty tubewells and deep tubewells. The discharge data has also been collected according to the category of the tubewells. The draft of a single tubewell is the product of the discharge and the running hour of the particular tubewell. Hence the draft of each category of tubewells has been calculated and summed up to obtain the total draft due to irrigation provided by the Agri-Irrigation department, Hugli. The table 5 shows the calculations for the groundwater draft by deep tubewells.

Table 4: **Calculations of Total Groundwater Draft by Deep Tubewells.**

| Type of Tubewells | Groundwater Draft (ham) |
|---|---|
| Deep Tubewells | 1418.32 |
| Heavy Duty Tubewells | 129.98 |
| Medium Duty Tubewells | 70.35 |
| Low Duty Tubewells | 77.36 |
| Total | 1696.01 |

Source: Calculated by authors based on the data provided by Agri-Irrigation department, GoWB.

### 3.4 Computation of Groundwater Draft due to Domestic purpose:

Draft due to domestic purpose: The Public Health Engineering has made the 'Sajal dhara' scheme for providing domestic water supply to this area. They supply at a rate of 40 litres/capita/day. The population of Pandua block has been projected to 2007 based on census data from 1961 to 2001. The projected population figures to 339842 based on $2^{nd}$ degree polynomial equation at $R^2$= 0.99. Thus the total draft for domestic purpose amounts to 497.17 ham.

Table 5 shows the total amount of groundwater draft by all the groundwater abstraction units. It compiles the total groundwater draft by shallow tubewells, deep tubewells and the draft for domestic purpose.

Table 5: **Total Groundwater Draft from All Sources**.

| Type | Groundwater Draft |
|---|---|
| Irrigation by Shallow Tubewells | 7666.59 |
| Irrigation by Deep Tubewells | 1696.01 |
| Domestic Draft | 496.17 |
| Total | 9858.77 |

Source: Calculated by authors.

## 4. Conclusion:

The total amount of groundwater recharge in the year 2007 amounts to 18117.24 ham while the total groundwater draft from all the sources within the block amounts to 9858.77 ham. Therefore the stage of groundwater development is 52.23%. But still there is either a pre-monsoon or post-monsoon fall of static water level each year for the last 40 years. The answer to research question of this particular study is that the fall of static water level of this block is not absolutely due to the groundwater drafting for irrigation purpose. The groundwater draft for domestic use is very less and can be considered as insignificant reason contributing to the fall of static water level. From the lithological settings of this area which is completely alluvial in nature it can be concluded that the groundwater flows following the hydraulic gradient to the adjacent blocks. Thus any decision regarding the management of groundwater of this particular block has to be taken keeping the groundwater budget of this block.

**Acknowledgement**: The first author is grateful to CSIR for providing funds for research. The authors are also grateful to State Water Investigation Directorate, West Bengal and Agri-Irrigation Department West Bengal for providing data.

REFERENCE:

[1]. Acharyya, S. K. (2005). *Arsenic levels in Groundwater from QuartenaryAlluvium in Ganga plain and the Bengal basin, Indian subcontinent: Insights into Influence of Stratigraphy. Gondwana Research*, Vol 8, Issue 01,pp55-66, 2005

[2]. Census of India. (1961). *Primary Census Abstract.* West Bengal: Directorate of Census Operations.

[3]. Census of India. (2001). *Primary Census Abstract.* West Bengal: Directorate of Census Operations.

[4]. Chatterjee, R., & Purohit, R. R. (2009, 6 12). *Estimation of replenishable groundwater resources of India and their status of utilization. CurrentScience*, Vol 96, Issue 12,pp1581-1591 2009.

[5]. Department of Water Resources Investigation & Development, GoWB. (2012). *Report on Fourth Minor Irrigation Census in West bengal (2006-2007).* Kolkata.

[6]. Johnson, A. I. (1967). *Specific Yield-Compilation of Specific Yield of Various Materials.* Washington: United States Government Printing Office.

[7]. Majumder, A., & Sivaramakrishnan, L. (2013). Computation of Loss of Storage of Groundwater During 1975-2008: A study in Pandua Block of Hugli District,West Bengal. *International Journal of Current Research* . Vol 5, Issue 08, pp2351-2355, 2013

[8]. Majumder, A., & Sivaramakrishnan, L. (2012). Water Balance of Pandua Block in Hugli district, West Bengal. *Interacadamecia* . Vol 16, Issue 01, pp131-136, 2012

[9]. National Bureau of Soil Survey. (2001). *Technical Bulletien88:Soils of Hugli District for Optimising Landuse.* Kolkata: National Bureau of Soil Survey.

[10]. Raghunath, H. M. (1982). *Groundwater.* New Delhi: New Age International.

[11]. Shah, T. (2009). *Taming the Anarchy: Groundwater Governance in South Asia.* Vol 28, Issue 3, pp281-284, 2010

[12]. Shankar, P. S., Kulkarni, H., & Krishnan, S. (2011, 1 8). *India's Groundwater Challenge and the Way Forward. Economic & Political Weekly*, Vol XLVI Issue 2, 2011

[13]. West Bengal Pollution Control Board. (2009). *Water Resource And Its Quality In West Bengal.* Kolkata: West Bengal Pollution Control Board.