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RESEARCH ARTICLE

COMPUTATION OF LOSS OF GROUNDWATER STORAGE DURING 1975-2008: A STUDY IN PANDUA BLOCK OF HUGLI DISTRICT, WEST BENGAL

Arijit Majumder* and Dr. Lakshmi Sivaramakrishnan

Department of Geography, The University of Burdwan, Golapbag, Burdwan. PIN-713104, India

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ABSTRACT

Alluvial areas in india are 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 total loss of groundwater storage in Pandua block of Hugli district, West Bengal. The area is a meander flood plain with continuous fall of groundwater level. Borehole points of the area have been taken and the length has been differentiated according to their texture corresponding to respective specific yield to calculate the total loss of groundwater in the area.

INTRODUCTION

Groundwater is commonly understood as the water occupying all the voids within the geological stratum (Todd, 2006). Groundwater occurs in type of geological formations like aquifers, aquiclude and aquitard. An aquifer is defined as a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs (Todd, 2006). An aquifer may comprise either one or several water bearing srata having either similar or different geologic ages, lihologic features and infiltration properties, hence it may be single layered or multi-layered (Klimentov, 1983). Aquiclude and aquitard did not yield sufficient amount of water to wells. Recharge of an aquifer or discharge from an aquifer represents the change in storage volume within an aquifer. Groundwater storage is defined as the volume of water that could be theoretically extracted if the aquifer were completely drained (Dixon, 2003). In case of a confined aquifer the storage coefficient of an aquifer is the volume of the water discharged from a vertical column of aquifer standing on a unit area as the water level (piezometric level) falls by a unit depth (Raghunath, 1982). For unconfined aquifers the storage coefficient is equal to specific yield. Specific yield (Sy) of a soil or rock is the ratio of the volume of water (Wy) that after saturation, can be drained by gravity to its own volume (V) (Todd, 2006).

$$Sy = Wy / V$$

Rapid rise of population has created a huge demand for water in agriculture, industrial and domestic sectors 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 (West Bengal Pollution Control Board, 2009). Thus the gap is supplemented either by transboundary water or by over exploitation of groundwater (West Bengal Pollution Control Board, 2009). 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 (Rawal,2001). 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 (West Bengal Pollution Control Board, 2009). The groundwater in West Bengal is over-exploited and out of 341 blocks in West Bengal 38 blocks are under critical or semi-critical condition (Ray and Sekhar, 2009). The present study deals with the change of storage of groundwater in Pandua block of Hugli district in West Bengal during the period 1975-2008. This block is a semi-critical block (Ray and Sekhar, 2009). According to Central Groundwater Board a semi-critical block is one where there is either a pre-monsoon or post-monsoon fall of groundwater level, but the stage of groundwater development is less than 100percent (West Bengal Pollution Control Board, 2009). It lies in the southern part of the state. 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 (Census of India, 2001). The area lies within a interfluve where the river Hugli flows east and the river Damodar on the west. The area is a meander flood plain which represents the newer alluvium (National Bureau of Soil Survey, 2001). The newer alluvium or the Holocene deposition is characteristically unoxidised and consists of sand, silt and clay mainly deposited in fluvial settings (Acharyya, 2005). Groundwater occurs within a thick zone of saturation under water table condition in the entire Hugli district except a small portion to the west beyond river Darakeswar (Bhattacharjee, 1982). This particular block is selected for the study as there has been continuous fall of static water level in the selected time period i.e. 1975-2008. The change in storage of groundwater actually represents the amount of water that has been lost from the system and which is hardly replenishable. The main objective of the study is to study calculate the total loss of groundwater storage of Pandua block of Hugli district.

MATERIALS AND METHODS

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

1. Static water level data has been collected from State Water Investigation Directorate, West Bengal.

**Corresponding author:* Arijit Majumder, Department of Geography, The University of Burdwan, Golapbag, Burdwan. PIN-713104, India

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.

been built to vectorise all the mouzas of the block. The centroid of required mouzas has been selected for plotting the borehole points. Thus a point vector has been created on the base map with 56 points to locate the positions of the boreholes. 15 sample points of the boreholes are then selected close to a cross-section line which runs

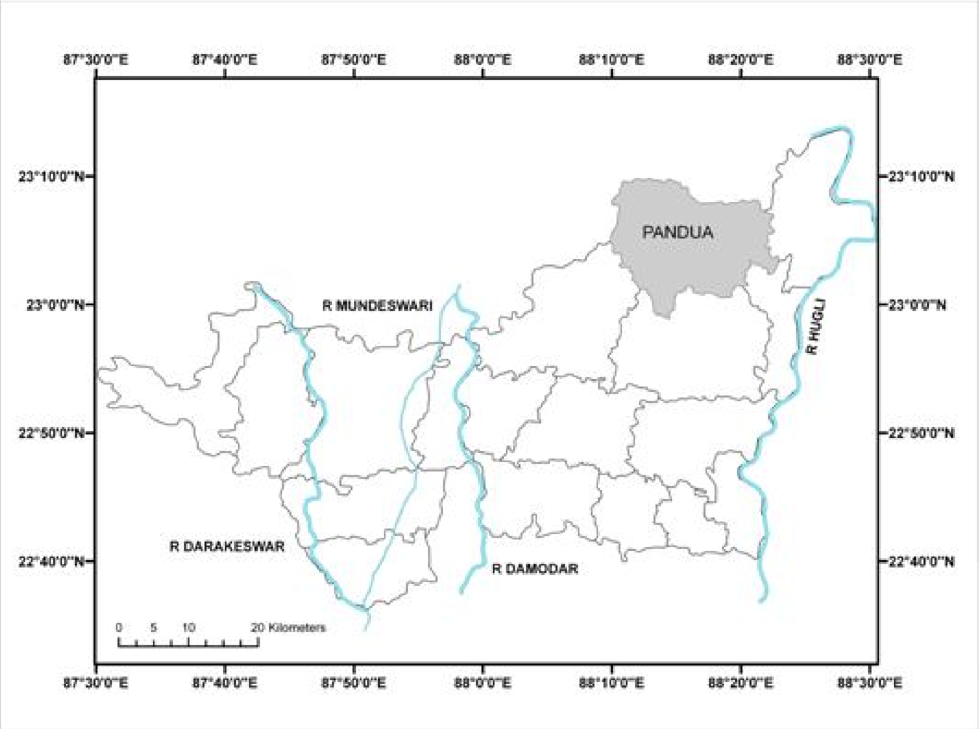

Fig. 1. Location of Pandua block in Hugli district (Prepared on the basis of map of Census handbook of Hugli district, West Bengal,1961)

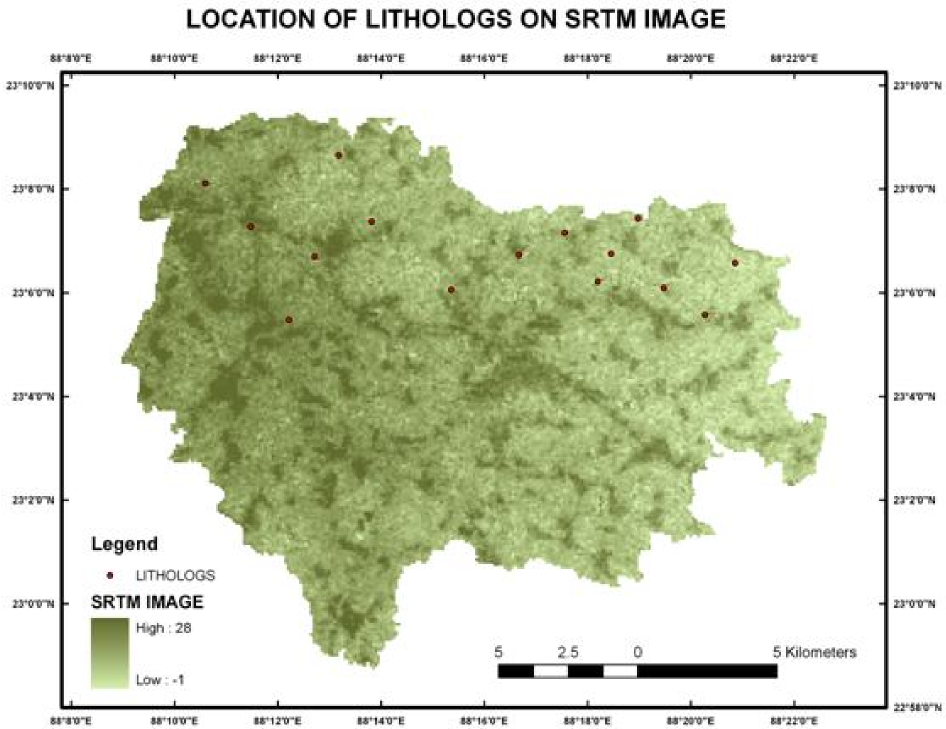

Fig. 2. Location of sample borehole points on the subset SRTM image of Pandua block for preparing the Panel diagram

Storage is a function of specific yield of soil and rock and hence the detail analysis of the lithology of the study area is extremely important. Borehole data was collected from Agri-Irrigation Department to study the lithology of the area. For the purpose of plotting the borehole data the reduced level of the borehole data are necessary. A block map of Pandua block has been georeferenced in Arc GIS 9.3 with an RMS error of 0.00011. A polygon layer has in west to east orientation across the northern part of the block. The reduced levels (R.L.) of the point vectors are necessary for drawing the Panel diagram. Shuttle Radar Topographic Mission (SRTM) has been processed and the point vectors of the boreholes were superimposed to get the reduced level of the point vectors. Figure 2 shows the bset SRTM image of Pandua block with the sample borehole points selected for drawing the panel diagram. The Panel diagram is then prepared with the help of 21st Century GIS 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 litholog of the study area. From Figure 3 it is clear that the lithology of the area is alluvial and the type of aquifer can be considered as unconfined in character though in true sense alluvium is considered as leaky aquifer. Hence to calculate the change in groundwater storage of the area we have considered the mathematical calculations for the unconfined aquifer.

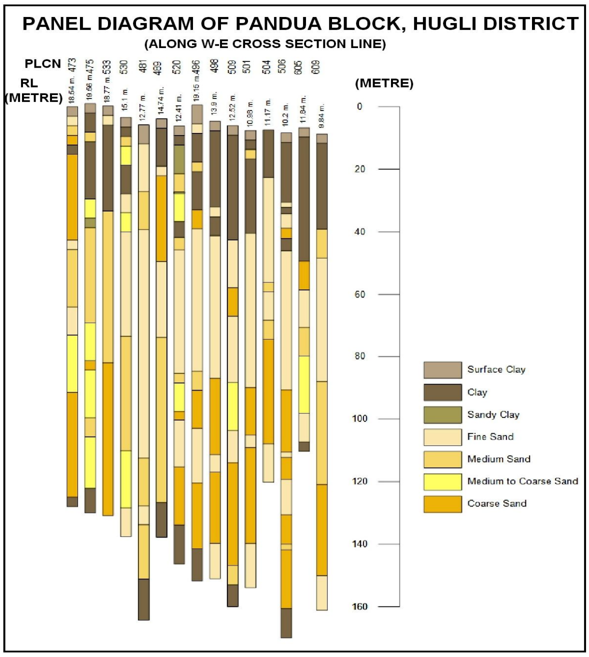

Fig. 3. Panel diagram showing the lithology of Pandua block (Prepared by authors based on the data provided by Agri-Irrigation department, Hugli)

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

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

RESULTS AND DISCUSSIONS

Change of Static water table

The static water level of the study area changes with seasons and is functionally related to the month of a year. It is defined as the level of water in wells in an undisturbed and no pumping condition. Here the average static water levels of the observation wells have been taken for the study. According to the availability of data the month of March has been selected to study the trend of static water level over years from 1967 to 2008. Figure 4 represents the static water level of 1967, 1975, 1998 and 2008.

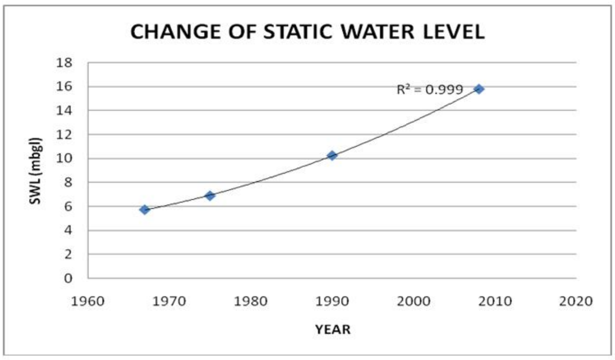

Fig. 4. Change of Static water level (as computed by authors on the basis of data provided by SWID)

Figure 4 shows that the static water level has fallen from 5.715mbgl to 15.78mbgl. The fall is more than 10 metres in 40 years. Figure 4 also depicts that the fall is 1.16metres in 8 years i.e. from 1967 to 1975, 3.37 metres during 15 years ranging from 1975 to 1990 while it is 5 metres in 10 years from 1998 to 2008. The curve thus states the rapidity of the phenomenon with time.

Calculation of Loss of Storage from 1975-2008

Static water level data of 19 borehole points are available in the month of March 1975. The average static water level of March 1975 has been taken and compared with the static water level of March 2008 to compute the loss in storage during the said period in Pandua block of Hugli district. The static water level data of the month of January, April, August and November was provided from the office of State Water Investigation Directorate from 1998 to 2008. Based on that data, a 2nd degree polynomial equation was adopted for interpolating the value of static water level in the month of March. The fluctuation of static water level has been found to be 8.91 metres, starting from 6.87 metres below ground level in 1975 to 15.78 metres below ground level in 2008. The length of fall of the static water level has been differentiated according to their texture. The differentiated length has then been multiplied by specific yield of their respective texture. 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

The summation of the product of differentiated length and specific yield of each of the borehole has been taken. The mean of the 65 datasets has been calculated and then multiplied with the area of the block to get the net change in storage which is actually the total loss produced in this area.

Table 2. Differentiated length of fluctuation of static water level

SL	TEXTURE	L1	TEXTURE	L2	TEXTURE	L3	TEXTURE	L4
1	CLAY	8.38	SANDY CLAY	0.53				
2	CLAY	8.37	COARSE SAND	0.54				
3	CLAY	8.91						
4	CLAY	8.91						
5	CLAY	8.91						
6	COARSE SAND	8.91						
7	CLAY	8.91						
8	CLAY	8.91						
9	CLAY	2.27	FINE SAND	3.68	SANDY CLAY	2.4	CLAY	0.54
10	SANDY CLAY	8.37	FINE SAND	0.54				
11	CLAY	8.91						
12	CLAY	8.91						
13	MEDIUM SAND	2.28	CLAY	6.63				

14								
15	CLAY	8.91						
16	CLAY	8.91						
17	CLAY	8.91						
18	CLAY	8.91						
19	CLAY	8.91						
20	CLAY	8.91						
21	COARSE SAND	2.28	CLAY	6.63				
22	CLAY	8.37	MEDIUM SAND	0.54				
23	CLAY	5.32	SANDY CLAY	3.05	COARSE SAND	0.54		
24	SANDY CLAY	2.27	CLAY	6.64				
25	FINE SAND	2.23	CLAY	6.68				
26	COARSE SAND	2.27	CLAY	6.64				
27	FINE SAND	2.28	CLAY	6.63				
28	CLAY	8.91						
29	CLAY	8.91						
30	CLAY	8.91						
31	CLAY	8.91						
32	CLAY	8.91						
33	CLAY	2.27	MEDIUM SAND	3.05	CLAY	3.59		
34	MEDIUM SAND	2.27	CLAY	6.64				
35	CLAY	8.91						
36	CLAY	8.91						
37	FINE SAND	5.32	COARSE SAND	3.59				
38	CLAY	8.91						
39	CLAY	2.28	FINE SAND	3.05	CLAY	3.58		
40	CLAY	8.38	FINE SAND	0.53				
41	CLAY	2.28	FINE SAND	3.05	CLAY	2.8	COARSE SAND	0.78
42	CLAY	5.32	COARSE SAND	3.05	CLAY	0.54		
43	COARSE SAND	2.28	FINE SAND	2.85	MEDIUM SAND	3	COARSE SAND	0.78
44	CLAY	8.37	FINE SAND	0.54				
45	CLAY	8.91						
46	CLAY	8.91						
47	CLAY	8.91						
48	CLAY	8.91						
49	CLAY	5.33	MEDIUM SAND	3.58				
50	CLAY	8.91						
51	CLAY	2.27	MEDIUM SAND	3.05	CLAY	3.59		
52	CLAY	8.37	FINE SAND	0.54				
53	MEDIUM SAND	2.28	COARSE SAND	6.09	CLAY	0.54		
54	CLAY	8.37	COARSE SAND	0.54				
55	MEDIUM SAND	2.28	COARSE SAND	3.04	CLAY	3.05	COARSE SAND	0.54
56	SANDY CLAY	8.67	MEDIUM SAND	0.24				
57	CLAY	8.91						
58	FINE SAND	8.91						
59	CLAY	8.37	MEDIUM SAND	0.54				
60	FINE SAND	8.37	CLAY	0.54				
61	CLAY	8.37	SANDY CLAY	0.54				
62	FINE SAND	5.32	COARSE SAND	3.05	CLAY	0.54		
63	CLAY	8.91						
64	SANDY CLAY	2.27	COARSE SAND	6.64				
65	MEDIUM SAND	2.27	COARSE SAND	6.1	MEDIUM SAND	0.54		

Source: Calculated by authors on the basis of data provided by SWID

Table 2 represents the calculation of the loss of storage in the area. Table 2 shows the differentiated length of textures of a vertical column ranging from 6.87 metres below ground level to 15.78 metres below ground level. The total loss in storage amounts to 17775 ham (hectare-metre) in 33 years. The fall of static water level is 8.91metres vertically in the block area in 33 years which actually amounts to 17775ham. To be more specific 177.75 squarekilometre-metre volume of water has been lost from the system i.e. the block which is 276.4 squarekilometre in area. Thus it can be stated that the groundwater condition exist in an alarming state in Pandua block of Hugli district in West Bengal. Hence proper management of water resource even in the alluvial regions which are normally considered as groundwater potential zone is extremely necessary. Sustainable use of groundwater will decide the future personality of the highly alluvial tract of this part of Hugli district.

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