ISSN 1605-2021

লোক-প্রশাসন সাময়িকী
চতুস্ত্রিংশত্তম সংখ্যা
মার্চ ২০০৫/ফাল্গুন ১৪১১

Hydrogeological Study for the Determination of Groundwater Potentiality : A Case Study in Netrokona Sadar Upazila

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Abstract: *Bore log data of 52 deep tube-wells installed in Netrokona Sadar Upazila were interpreted to obtain a clear picture of hydro geological properties of northeastern region of Bangladesh for real assessment of groundwater resource and its optimum utilization. The main aquifer or exploitable aquifer thickness varied from 19.22 meter to 71.37 meter having thickness of 39.65 meter. The main aquifer is found to be well productive and potential for water abstraction. The coefficient of transmissibility (T) and coefficient of storage (S) were determined from pumping test data by using Jacob's time-drawdown Method and Theis Recovery Method. Transmissibility varied from 1043 to 2939 m²/day and coefficient of storage varied from 0.00006 to 0.0097. The average specific yield value has been estimated as 8 by using USGS Hydrologic Lab-provisional values. The aquifer may be categorized as confined. The hydraulic properties ranked the aquifer highly potential for groundwater exploitation.*

Introduction

Water is the most indispensable commodity for the sustenance and well-being of mankind. Modern civilization imposes heavy demands on water. The largest available source of fresh water lies under ground. Groundwater now-a-days, is considered as one of the important resources to form a significant component in the agriculture development programme. It also plays vital role for domestic, industrial and municipal purposes. In Bangladesh average rainfall is very high but it does not occur uniformly in all seasons rather skewed to high monsoonal character. Therefore groundwater becomes a vital resource for irrigation during half of the year i.e. dry months. The development of groundwater resources plays a very important role in increasing agricultural production to meet the increasing food demand of the country. The surface water is still now unable to meet the irrigation demand. Most of the surface water bodies dry up in irrigation season. Moreover, river flows of the country are gradually decreasing in the dry season due to gradual withdrawal of

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water in the upstream rivers by the neighbouring country. Therefore, utilization of ground water is increasing day by day at an accelerated rate. But this resource is not unlimited. Unplanned withdrawal may lead to a dangerous imbalance in the local geology. So proper management of this resource is a crying need of the country. The future strategies for the management of this renewable resource and its judicial utilization completely depend on the basis of extensive studies on groundwater reserve. The groundwater reserve depends on the various factors governing the availability and dependability of the resource among which the lithological and hydraulic characteristics of the aquifer are two very important factors. Many investigations were carried out in the past related to aquifer lithology and hydraulic properties. Most of the works are confined to northwest region of the country. A very little work has so far been done on the northeastern region. Therefore for assisting in planning and developing ground water resource in the northeastern region by providing reliable and complete database, an intensive study and critical analysis of data must be required. With a view to this, a study was undertaken in Netrokona sadar upazila to determine the lithological characteristics and hydraulic behaviour of the study aquifer.

Review of Literature

a) Lithology: The country is mostly covered by unconsolidated to poorly consolidated sediments deposited by the rivers passing through which were thick over most areas and form good water bearing formations (Curray and Moore, 1971). Most parts of the country are covered by the recent alluvial deposits. Their characters changed laterally and with depth owing to the frequently shifting and meandering of the streams and reworking of the sediments during the depositional history. The thickness varied from a few hundred to more than thousand metres. Over much of the area, silts and clays predominate on the top 15 to 25 metres, whereas sands are the major constituents in the deeper part. Gravels are found in some locations also. (Morgan and McIntire, 1959). On the basis of the hydro-geologic study of UNDP/BWDB (1982) and MPO (1995) it was identified that the aquifer system throughout the country is generally made up of the upper clay and silt layer (about 20 m thick), composite aquifer (varies from about 3 to 60 m) main aquifer (extends from a depth of 150 to about 300 m) and deep aquifer (300 to 1000 m).

In Muktagacha Upazila of Mymensingh district, a hard clay layer of 20 m thickness existed above a 5 to 10 m thick fine sand layer. Below the hard clay layer the formation was layered with fine, medium, coarse sands and gravels up to 100 m from the surface (Ahmed et al, 1991). Semi confined nature of the aquifer was reported. Since most of the deep tube-wells were installed within this (100m) depth, information beyond this was not known.

Mojid (1993) reported that the sub-surface lithology of Trishal upazila was represented by the upper part of the formation consisted in mainly of clay, silty clay and fine sand layers while the lower part constituted the water bearing formation was formed with medium coarse sand, coarse sand and also their mixtures. A thick hard clay layer of thickness ranging from 18 to 150 m existed over the main aquifer. The aquifer was semi-confined in nature.

It was reported that surface clays arranged 10m in thickness in southern part of Mymensingh district but increased rapidly to over 30m in the north. This was accompanied by a reduction in thickness of aquifer materials within the top 100 m, as extensive aquiclude clays existed from 20 to 50 m and 96 to 76 (McDonalds and partners limited, 1983)

In Netrokona sadar upazila, the depth to top of the main aquifer was 40 m to 50 m thickness of aquitards above the main aquifer was 20m to 30m (Mott McDonald, 1992).

Hydraulic properties of the aquifer

Bhuiyan et al., (1977) evaluated the aquifer's hydraulic properties of Mymensingh -Tangail area. It was found that the transmissivity varied from 1409.00 to 1681.81 m^2/day for Dewanpur, 1312.27 to 2090.90 m^2/day for Lucia (Nagbari), 1327.27 to 1681.81m^2/day for Jamalpur and 1327.27 to 1927.27 m^2/day for Modhupur; while the storativity varied from 0.0434 to 0.0556 for Dewanpur, 0.0110 to 0.0175 for Lucia, 0.013 to 0.0445 for Jamalpur and 0.0710 to 0.0250 for Modhupur.

The transmissivity varied from 1250.00 to 4440.90 m^2/day in Jamalpur district (Chowdhury, 1978). Ali (1978) observed the transmissivity value of 148.81 to 1954.54 m^2/day for Muktagacha, 1009.09 to 1863.63 m^2/day for sadar upazila of Mymensingh.

The average value of storativity, transmissivity and permeability of Muktagacha aquifer were found as 0.0069, 1764d m^2/ay and 30.4m/day respectively (Ahmed et al., 1991). They also ranked the aquifer to be good and potential.

Khan (1989) found a range of transmissivity of 3128 to 5970 m^2/day, and storage coefficient of 0.0007 to 0.0356 for Tangail sadar upazila.

Hyde (1979) reported that storage coefficient for Bangladesh was between 0.10 and 0.15.For entire Bangladesh, UNDP (1982) reported that transmissivity between 100 and 7020 m^2/day and storativity values between 0.0003 and 0.0072 respectively.

Mott McDonald (1992) reported that permeability of the main aquifers for Netrokona Sadar upazilla was 60 to 70m/day and specific yield at 10m was 5 to 6%.

From the review of the past literature it is revealed that a very few research has so far been conducted in the study area to determine the lithological and hydraulic properties. The present study will fulfill the gap.

The main objective of the present study is to evaluate the hydro-geologic properties of Netrokona aquifer and the potentiality of the ground water abstraction. The specific objectives are as follows:

1) To determine the aquifer (water bearing formation) on the basis of subsurface lithology i.e. thickness of the different aquifer.

2) To estimate the hydraulic and hydrogeological properties of the aquifer e.g.

   a) Specific yield.
   b) Transmissibility.
   c) Storage coefficient.
   d) Specific drawdown.
   e) Specific capacity.

Methodology

1) Lithological Data Analysis

Borelogs of 52 deep tube-wells have been collected from Bangladesh Agricultural Development Corporation (BADC), Netrokona region. These were prepared by BADC during construction of the tube-wells. Vertical cross sections of subsurface lithology have been divided into four zones depending on the lithological constituents and the aquifer. By lithological analysis specific yield of the aquifer has been determined by using US Geological Survey Hydrologic Lab- Provisional values. The hydrological laboratory of the US Geological Survey in Denver, Colorado, under the direction of AI Johnson had undertaken a research study on the specific yield of unconsolidated materials based on lithological analysis. The results of the work were available and are shown in Table 1. These values have been used in estimating the specific yield of the study area in the present work. The specific yield of any volume of geologic material can be obtained by summing up the specific yield values of all unit volumes it contains. Since nearly all such zones include various types of materials with different specific yield, it is necessary to weigh each material according to its proportions of the entire volume.

Table-1: Values of Specific Yield after U.S.G.S. Hydrologic Lab-Provisional Values

Material	**Specific yield (%)**
Clay	1
Silty Clay	2
Sandy Clay	3
Clay Silt	5
Silt	7
Clay Sand	7
Sandy Silt	14
Silty Sand	20
Fine Sand	26
Medium Sand	35
Coarse Sand	33
Sand (undifferentiated)	32
Fine Gravel	25
Medium Gravel	20
Coarse Gravel	14

2) Pumping Test and Data Analysis

Pumping tests were conducted earlier by BADC during the installation of the deep tube-wells. While conducting the test, data on water levels were collected by avometers and stopwatches. Each test lasted for six (6) hours duration. During the first ten (10) minutes of the test, data were collected at one (1) minute interval, while for 10 to 30 minutes, 30 to 120 minutes and 120 to 360 minutes the time intervals were 5, 10 and 30 minutes respectively. The ground water level recovery data in each well were recorded after pumping was stopped. The same time intervals of pumping test were followed for the recovery test. Pumping test of eight (8) deep tube-wells were used for the determination of transmissibility and storage coefficient.

2(a) Determination of Hydraulic Characteristics

In the present study two standard methods were used to estimate Transmissibility and Storage Coefficient. e.g.

(1) Jacob's Time - Drawdown Method.

(2) Theis Recovery Method.

2(a)(1) Jacobs's Time - Drawdown Method

This method gives fair predictions only when steady state condition prevails or steady shape condition developed. This method is especially applicable to artesian conditions since it takes long period to reach steady shape conditions in water table aquifer. The method is extremely useful in making long term predictions of withdrawals from aquifers which boundary conditions are known. This method is valid for the value of u <0.01. The early drawdown data of pumping test is omitted in this method. The time-drawdown graphs were prepared on semi-log papers with drawdown in the vertical axis (arithmetic scale) and time on the horizontal axis (logarithmic scale). The slopes of the straight line would be proportional to the pumping rate and transmissibility. Jacob derived the following equations for determination of transmissibility and storage coefficient from the time -drawdown graph.

$$T = \frac{2.3Q}{4\pi\Delta S} \qquad (1)$$

$$S = \frac{2.25Tt_o}{r^2} \qquad (2)$$

Where,

Q = pumping rate, m^3/day
T = transmissibity, m^2/day
t_o = time, at which the straight line intersects the zero drawdown, min.
S = storage coefficient.
r = distance of the observation well from the pumping well.

2(a)(2) Step- Drawdown Pumping Test

Step- drawdown pumping test data of eight deep tube-wells of the study area were collected from BADC, Netrokona office. Among them two were used for four stepped tests and the rest were used for the three-stepped test. The specific drawdowns were determined for each step by the well discharge of each step. Every step lasted for 100 minutes. By inverting the specific drawdown values specific capacities were also calculated. The average values of the three and four steps were determined. The results were interpreted to help selecting the appropriate tube well technology.

Results and Observation

The present study was undertaken in generating detailed information about ground water condition on Netrokona Sadar upazila. During the study the collected data and relevant information were analyzed by established methods and were interpreted systematically. The results and findings generated from the study were provided and discussed in the following:

Sub-Surface Lithology of the Investigation Area

The lithological analysis was carried out over the study area. It was conducted based on 52 bore logs existing installed deep tube-wells.

Vertical Cross Sections

The vertical cross-sections of subsurface lithology have been contracted which showed the variations in lithological sequences from place to place. They were grouped according to unions. According to lithological constituents and on the basis of aquifer types the subsurface layers were divided into four zones namely; zone I, II, III, IV. The thickness of zone I, II and IV are shown in Table 2, 3 and 4. Their descriptions are given below :

Zone I

This is the uppermost zone, which is composed mainly of clay and silt. This zone found to be extended from 2.44 m to 16.47 m bellow the ground surface having the average of 8.2m (Table 2). Because of its lithological character, it is characterized by low permeability and productivity. Most of the dug wells are situated in this zone.

Zone II

This zone is found to be composed of fine sand and medium sand or fine to medium sand. The thickness of this zone varies from 3.05 m to 33.25 m having the average thickness of 22.27 m (Table 3). It is characterized by moderate permeability because of which all types of hand tube wells and some shallow tube-wells are installed in this zone. It can be considered as composite aquifer.

Zone III

This zone is another clay layer mixed with silt or fine sand. The thickness was found to vary from 3.05 m to 28.06 m having average thickness of 12.2 m. This zone is also low permeable and low productive. This may be considered as aquitard from lithological point of view.

Zone IV

This zone was found to be composed of medium to coarse sand, coarse sand and gravels. The thickness of this zone was ranging from 19.22 m to 71.37 m having average thickness of 39.65 m (Table 4). This zone is highly permeable and productive from the lithological point of view. That is why most of the deep tube-wells and shallow tube-wells were installed in this zone. This zone can be regarded as main aquifer.

Table-2 : Upper Clay & Silt Layer Thickness (m) Obtained From 52 Bore Logs

Well No	Thickness	Well No	Thickness
1	16.17	37	05.19
9	05.19	38	05.19
12	05.19	39	05.19
13	05.19	40	02.44
14	13.42	41	05.19
15	10.68	42	10.68
16	13.42	44	05.19
17	13.42	45	13.42
17	10.68	46	07.93
19	02.44	47	10.68
20	07.93	48	02.44
21	05.19	49	02.44
22	05.19	50	02.44
23	10.68	51	10.68
24	00.68	52	07.93
25	02.44	53	05.19
26	05.19	69	16.47
27	05.19	57	10.98
29	05.19	4/k	03.05
30	16.17	3/k	09.15
31	07.93	2/k	03.05
32	02.44	72	15.25
33	07.93	5/k	03.05
34	16.17	D1	12.20
35	16.17	D2	12.20
36	10.68	6	07.93

*Highest thickness: 16.47 meter
*Lowest thickness: 02.44 meter
*Average thickness: 08.24 meter

Table-3 : Composite Aquifer Thickness Obtained From 52 Bore Logs.

Well No	Thickness (m)	Well No	Thickness (m)
1	16.47	37	19.22
9	30.20	38	27.45
12	24.71	39	27.45
13	13.73	40	30.20
14	19.22	41	27.45
15	21.96	42	27.45
16	10.98	44	24.71
17	10.98	45	24.71
17	13.73	46	24.71
19	32.94	47	21.96
20	27.45	48	30.20
21	24.71	49	24.71
22	24.71	50	91.22
23	27.45	51	08.24
24	27.45	52	19.22
25	30.20	53	30.20
26	27.45	69	33.25
27	27.45	57	10.98
29	30.20	4/k	21.96
30	19.22	3/k	27.45
31	19.22	2/k	21.35
32	24.71	72	18.30
33	27.45	5/k	03.05
34	16.47	D1	09.15
35	19.22	D2	09.15
36	24.71	6	21.35

*Maximum thickness: 71.37 meter
*Minimum thickness: 19.22 meter
*Average thickness: 39.65 meter

Table-4 : Main Aquifer Thickness Obtained From 52 Bore Logs

Well No	Thickness (m)	Thickness (m)
1	24.71	32.94
9	54.90	57.65
12	30.20	32.94
13	24.71	52.16
14	24.71	43.92
15	19.22	29.56
16	52.16	38.43
17	31.72	32.94
17	35.69	24.71
19	38.43	32.94
20	38.43	52.16
21	19.22	32.94
22	30.20	60.39
23	60.39	49.41
24	24.71	27.45
25	71.37	30.20
26	57.65	63.75
27	32.94	31.72
29	38.83	33.55
30	32.94	33.55
31	30.20	33.55
32	24.71	36.60
33	71.37	42.70
34	68.32	36.60
35	65.88	42.70
36	32.94	32.94

*Maximum thickness: 71.37 meter
*Minimum thickness: 19.22 meter
*Average thickness: 39.65 meter

Evaluation of Specific Yield

Specific yield have been estimated based on lithological data analysis. The specific yield varied from 2 to 22 percent having the average value of 8 percent. (Table-5).

Table-4 : Main Aquifer Thickness Obtained From 52 Bore Logs

Well No	Thickness (m)
1	24.71
9	54.90
12	30.20
13	24.71
14	24.71
15	19.22
16	52.16
17	31.72
17	35.69
19	38.43
20	38.43
21	19.22
22	30.20
23	60.39
24	24.71
25	71.37
26	57.65
27	32.94
29	38.83
30	32.94
31	30.20
32	24.71
33	71.37
34	68.32
35	65.88
36	32.94

Thickness (m)
32.94
57.65
32.94
52.16
43.92
29.56
38.43
32.94
24.71
32.94
52.16
32.94
60.39
49.41
27.45
30.20
63.75
31.72
33.55
33.55
33.55
36.60
42.70
36.60
42.70
32.94

*Maximum thickness: 71.37 meter
*Minimum thickness: 19.22 meter
*Average thickness: 39.65 meter

Evaluation of Specific Yield

Specific yield have been estimated based on lithological data analysis. The specific yield varied from 2 to 22 percent having the average value of 8 percent. (Table-5).

Table-5 : Estimation of Specific Yield Obtained From 52 Bore Logs for Different Location

Well No	Sp. yield (%)	Well No	Sp. yield (%)
1	3	37	8
9	13	38	14
12	10	39	15
13	14	40	15
14	2	41	5
15	2	42	15
16	5	44	2
17	2	45	7
17	2	46	2
19	20	47	11
20	11	48	14
21	14	49	9
22	14	50	22
23	2	51	2
24	2	52	7
25	20	53	14
26	11	69	3
27	14	57	4
29	14	4/k	11
30	4	3/k	3
31	6	2/k	8
32	8	72	3
33	8	5/k	9
34	2	D1	2
35	2	D2	2
36	6		

*Average Specific Yield: Eight (8) percent.

Determination of Hydraulic Properties of the Aquifer

Analyzing pumping data by Jacob's time-drawdown method and Theis time recovery method, the hydraulic properties of seven places of the study area have been estimated which were shown in Table-6.

The coefficient of transmissibility (T) at Zila parishad, Medni, Kailati, Mougati, Singherbangla, Thakurkona was found to be 1043, 2755.62, 1469.67, 2593.53 and 2939 m^2/day respectively using Theis Recovery method. Using Jacobs time drawdown method the transmissibility at Satpai Graveyard and zila parishad was found to be 852.18 and 734.4 m^2/day respectively. The values of storage coefficient (S) were found to be 0.0049, 0.0033,0.0097, 0.0038, 0.0035, 0.00006, 0.00023 respectively at the places mentioned above. These results revealed that the storage co-efficient fell in the range of S values for confined aquifer (0.00005-0.005) except in one location (0.00006). The results (shown in Table 6) showed that the values of T varied widely with a minimum of 734.40 m^2/day to a maximum of 2939.00 m^2/day with a average value of 1800.51 m^2/day. UNDP (1982) reported that T value varies from 500 to 3000 m^2/day for this zone. So the aquifer properties estimated under this study might reasonably be accepted for evaluating the aquifers potentiality. Johnson (1966) categorized an aquifer with transmissivity of 1500 m^2/day or above to be good and potential for irrigation purpose. However, except the municipal area the aquifer in Netrokona Sadar upazila may be ranked as good and potential.

Table-6 : Transmissibility and Storage Co-efficient Values at Six Places of Netrokona Sadar Upazila

Well No	Name of the location	Parameter		Method used
		Transmissibility T (m2/day)	Storage coefficient S	
D1 (Production well)	Satpai Graveyard	852.18	0.00023	Jacob's time-drawdown method
D2 (Test Tubewell)	Zila parishad	1434.21	0.0015	Jacob's time-drawdown method
do	do	1043.00	0.00039	Theis Recovery method
D2 (Production well)	do	734.40	0.0049	Jacob's method
4/k	Medni	2755.62	0.00033	Theis Recovery method
72	Kailati	1469.67	0.0097	do
73	Singherbangla	2593.53	0.0035	do
5/k	Thakurkona	2939.00	0.00006	do

Specific drawdown and specific capacity were obtained from the step drawdown data for eight representative deep tube-wells at eight locations, which were shown in Table 7. As the specific drawdown and specific capacity are the useful concepts to indicate the productivity of both aquifer and wells, the results obtained here will be able to predict the efficiency of both aquifer and wells in the study area. The highest and lowest values of specific drawdown were found to be 228.11 m/cumec of the wells situated at Satpai graveyard and at Medni respectively. The specific capacities were 0.0043 and 0.013 cumec/m at the same places respectively. The average value of specific drawdown and specific capacity were 128.90 m/cumec and 0.0078 cumec/m respectively. These data will help in selecting the well discharge and well screen for the investigated area.

Table-7 : Specific Drawdown and Specific Capacity (Within Parenthesis) for Eight Deep Tube Wells Obtained from Step Drawdown Pumping Test.

Well No	Step – I Ft/cusec (Cusec/ft)	Step – II Ft/cusec (Cusec/ft)	Step – III Ft/cusec (Cusec/ft)	Step - IV Ft/cusec (Cusec/ft)	Average Ft/cusec (Cusec/ft)	Average M/cumec (Cumec/m)
D1	20.14 (0.05)	20.93 (0.05)	21.59 (0.05)	22.16 (0.05)	21.20 (0.05)	228.11 (0.0043)
D2	12.92 (0.077)	13.76 (0.072)	14.31 (0.07)	15.17 (0.066)	14.09 (0.071)	151.61 (0.0066)
5/k	8.63 (0.116)	9.67 (0.103)	9.72 (0.103)	--- ---	9.34 (0.107)	100.50 (0.0099)
71	12.30 (0.081)	13.27 (0.0753)	13.33 (0.075)	--- ---	12.97 (0.077)	139.56 (0.0072)
72	12.17 (0.082)	11.43 (0.088)	11.67 (0.086)	--- ---	11.76 (0.085)	126.54 (0.0079)
4/k	708 (0.141)	7.13 (0.140)	7.42 (0.135)	--- ---	7.21 (0.139)	77.58 (0.013)
73	8.92 (0.112)	8.17 (0.122)	8.25 (0.121)	--- ---	8.45 (0.118)	90.92 (0.011)
74	10.98 (0.091)	10.82 (0.092)	10.65 (0.094)	--- ---	10.82 (0.092)	116.42 (0.0086)

Overall Average : Specific drawdown - 128.90 m/cumec, Specific capacity - 0.0078 cumec/m

Conclusion

From the present study it can be concluded that the main aquifer is well productive and enough potential for water abstraction. The specific yield value (8) indicated the high potentiality of the Netrokona aquifer. From the values of transmissibility (T) and storage coefficient (S), the aquifer may be categorized as confined. Therefore the results obtained from this study can be considered as informative and indicative only and should not always be used as the absolute information for the entire area without further verification.

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