4th Annual Paper Meet and 1st Civil Engineering Congress, December 22-24, 2011, Dhaka, Bangladesh ISBN: 978-984-33-4363-5
Noor, Amin, Bhuiyan, Chowdhury and Kakoli (eds) www.iebconferences.info

Mathematical modeling for safe drinking water source identification: a case study

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ABSTRACT: Identification of a sustainable water source is a priority issue in case of urban water supply scheme. On 2010, Department of Public Health Engineering (DPHE) has taken up a project that includes safe drinking water supply through pipe network along with other urban utilities for 148 Paurashavas of Bangladesh. This paper presents the application of mathematical modeling for suitable water source identification. Mathbaria Paurashava of Pirojpur has been taken for case study. Water demand for the Paurashava area has been assessed up to the year 2040. Mathematical models are developed to assess the potential of surface water source and groundwater source against the present and projected water demand. For surface water model, the South West Regional Model (SWRM) is used, developed by Institute of Water Modelling (IWM). The flow simulation is carried out by Mike 11 software. The developed groundwater model of the study area comprises of 34 Upazilas. Modeling has been performed by an integrated Mike 11-Mike SHE software platform. The modeling results along with water quality data from primary and secondary sources reflect that, none of the surface water and groundwater is sufficient. Therefore, provision of an impounding reservoir has been proposed.

1 INTRODUCTION

Bangladesh has made tremendous improvement in water supply and sanitation over the last 3 decades. An estimation in 2004 shows that almost 98% of the populace have access to improved drinking water source (WHO & UNICEF 2006), a high extent for a low income country. About 97% of rural population and a significant portion of urban population depend exclusively on groundwater as a source. In 1993, it has been discovered that in significant areas of the country groundwater is contaminated with arsenic. Besides, a study in 2005 shows that groundwater in Barind area has depleted more than 8m during 1995-2005 (FAO & CEGIS 2006). Similar situation is observed in other parts of the country including the capital city, Dhaka. On the other hand, most of the surface water source in Bangladesh is usually polluted and requires treatment (Gupta et al. 2005). Therefore, identification of a safe drinking water source is a challenging task nowadays in Bangladesh.

In National Water Policy of Bangladesh it has been declared that, all necessary means and measures will be taken to manage water resources of the country in a comprehensive, integrated and equitable manner (National Water Policy 1999). To fulfill this target various authorities are evolved and working for supplying safe water to the people. Water supply coverage of Dhaka Water and Sewerage Authority (DWASA), Chittagong Water and Sewerage Authority (CWASA) and Rajshahi City Corporation (RCC) is 83%, 34% and is 84% respectively. Only 102 Paurashavas have intermittent piped water supply and the average coverage of which is 39% only (Bangladesh Water Utilities Data Book, 2006-07). Unfortunately among in total 309 Paurashavas, rest of them has no piped water supply scheme.

Under the above circumstances, Dept. of Public Health Engineering (DPHE) has taken up the project in hand, titled “Groundwater Management and TPP for Survey, Investigation, and Feasibility Study in Upazila and Growth Center level Paurashavas having no Piped Water Supply System”. The project is very much relevant to The National Policy for Safe Water Supply & Sanitation 1998 of the Government of Bangladesh. Institute of Water Modelling (IWM) has been employed in the project for “Mathematical Modeling for Safe Drinking Water Source Identification”.

While performing the project activities, detailed investigation has been carried out by IWM on surface and groundwater scenarios for each of the Paurashava and best option for water supply has been sorted out or proposed strongly. Validated Six Regional Models established earlier in IWM are being used for assessment of surface water and 22 new groundwater models are developed for groundwater assessment. The rationale of this paper is to identify a sustainable drinking water source for Mathbaria Paurashava, through mathematical modeling. Mike 11 software by Danish Hydraulics Institute (DHI) has been used for surface water simulation model and thus surface water resource assessment. Integrated Mike 11-Mike SHE platform has been used for groundwater modeling.

2 STUDY AREA

Mathbaria Paurashava is the only municipal area of Mathbaria Upazila of Pirojpur District. It is located in 22°17' N latitude and 89°57' E longitude. Presently, Mathbaria Paurashava is divided into 9 wards. Activities related to trade and commerce are increasing day by day and recently it has been emerged as one of the few A class municipal areas of Bangladesh. Though Mathbaria is a Class-A municipality, there was no piped water supply scheme till the initiation of the project mentioned in previous section. According to the project requirements, the whole municipal area has been modeled for pipe water supply network coverage for the year 2040. The water source options have been studied to distribute potable water to the municipal inhabitants.

3 CURRENT PRACTICE OF DRINKING IN MATHBARIA

Mathbaria does not have any piped water supply network at present. In fact, it suffers worse facility for drinking water as both the surface and groundwater source is not favorable for drinking. No major river is present in close proximity to the Paurashava. The nearest major river is Baleswar, flowing about 9km far away from the Paurashava to the east. Another regional major river known as Bishkhali is about 15km away from the Paurashava to the west. Only one renowned canal known as “Masua Khal” is present inside the Paurashava; which carries water throughout the year. But it is not suitable as a source since the water becomes brackish during March- April. On the other hand, excessive salinity exists even in deeper aquifer inside Mathbaria. For drinking purpose, people use pond water extracted from Pond Sand Filters (PSF). Also hand tube wells are used to extract drinking water from shallow aquifer, but most of them are contaminated with iron and arsenic. Therefore, identification of a suitable water source for a water supply scheme is a complex task in Mathbaria.

4 WATER DEMAND ASSESSMENT

A comprehensive water demand assessment is done for baseline year and projected up to the year 2040. The process of demand assessment is unique in a sense that it involves both spatial information and non-spatial information. Spatial information includes the GIS based maps of the area while demographic information is the only non-spatial data input.

GIS based maps are produced following the topographic survey conducted by IWM in 2010. Demographic data are collected from the population census reports (Bangladesh census 1981, 1991 & 2001) of Bangladesh Bureau of Statistics (BBS) for the years 1981, 1991 and 2001. For the baseline year 2010, demographic inputs are obtained from the Social Impact Assessment Survey (SIA) conducted in connection with the project. Population projection of the Paurashava is done at first, and then per capita demand for growing cities (Ahmed & Rahman 2000) is assigned to the population according to land use category of the Paurashava area. This practice is repeated for every five years from 2010 to 2040. Summary findings are shown in Table 1.

Table 1. Projected attributes of Mathbaria Paurashava

Attributes	2010	2015	2020	2025	2030	2035	2040
Growth Rate	2.837	2.828	2.819	2.810	2.801	2.792	2.783
Population	19,818	22,783	26,180	31,810	36,521	43,233	49,593
Water Demand (m^3/d)	436	652	952	1590	2414	3680	5330
Water Demand (m^3/d), including backwash for treatment plant.	459	689	1010	1691	2576	3940	5725

5 SURFACE WATER MODELING

Perennial rivers, reservoirs, lakes and ponds constitute the surface water source. Limitations like water availability, water quality, environmental degradation, physical locations, hydrology, salinity etc to be checked before selecting surface water as a source.

Assessment of available surface water for abstraction under consideration for water supply to Mathbaria Paurashava was carried out for potential sources from a nearby river like the Baleswar. The Baleswar is a defined secondary river with enough flows throughout the year and significant exploitable discharge even in the arid season. The origin of Baleswar River is from the Madhumati River. It has flown towards south direction and a number of secondary rivers namely Swarupkati, Kaliganga and Fanguchhi Rivers etc., join the Baleswar River. The river can be used as a sustainable surface water source after a detailed level study for constructing a surface water treatment plant for supplying drinking water to the consumer in the Paurashava. Mathbaria Paurashava intake point is located in the South West Regional Model (SWRM) developed earlier by IWM.

Water availability assessment for the Paurashava was carried out from long-term simulated discharge (comprising of 20-years model run) of validated model available at IWM. Data collection and updating / validation of models are carried out by IWM each year for various project purposes. However, for each project the requirements of the generated model outputs are customized for specific purposes for which they are to be used; as in case of this project, the public water supply.

5.1 *South West Regional Models*

The South West Regional Model (SWRM) of Bangladesh was developed at IWM primarily for planning studies of the secondary rivers in the regional model shown in Figure 1. It covers the major river networks of the SWR of the country which includes the administrative divisions of Barisal and Khulna. A Map showing the river systems around Mathbaria Paurashava is given in Figure 1.

The SWRM is one of the 6 (six) regional models of Bangladesh developed under erstwhile Surface Water Simulation Programme, Phase-II (SWSMP-II). The development of the model was initiated in December 1989 and the data collection was initiated in April 1990. The present model was primarily conceived as Pilot Models for two sub-regions, viz., the South West (SW) and the South Central (SC) models which were later developed into Full Models. The present model was developed as a single regional model developed towards the end of SWSMP-II upon merging of the two separate models mentioned above to a single model i.e. the SWRM.

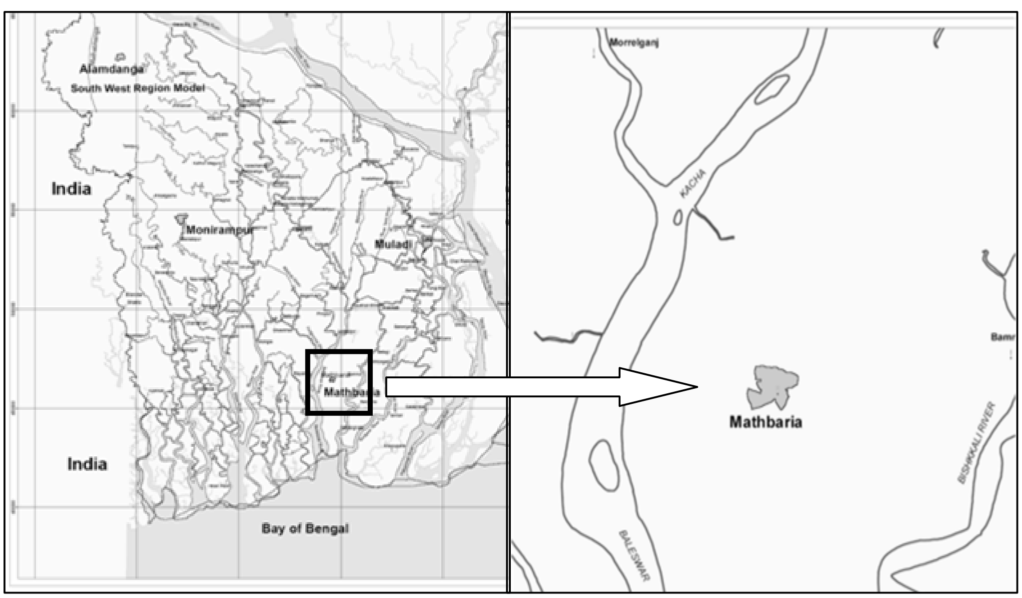

Figure 1. The position of Mathbaria Paurashava in SWRM

The whole model is calibrated and validated by using historical data of 20 years. This simulation model is used to forecast the water availability for supplying drinking water for Mathbaria Paurashava. A sample of calibration of water level at upstream of Pirojpur on Baleswar river is presented below in Figure 2.

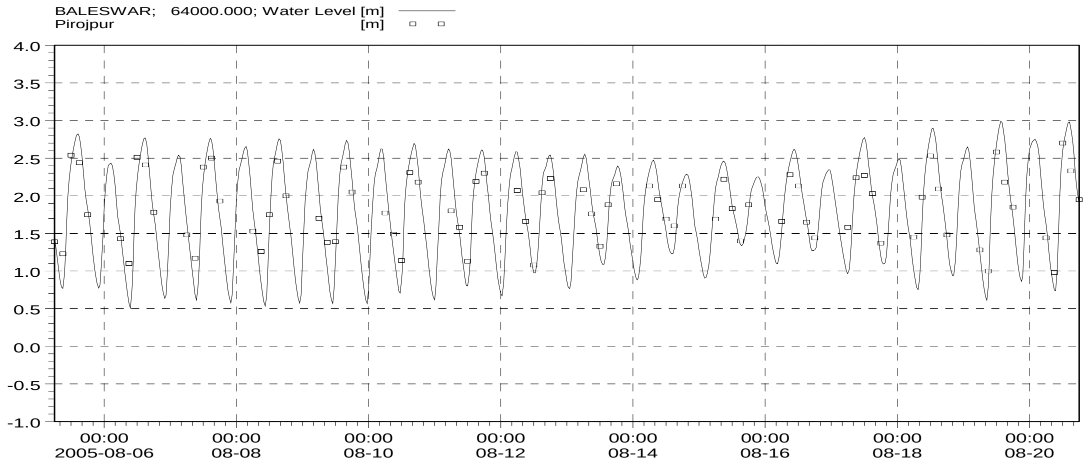

Figure 2. Calibration of water level upstream Pirojpur on Baleswar river

5.2 *Surface water availability assessment*

Surface water availability was assessed in terms of flow-duration curves using simulated data for year round discharge at the selected location. Flow duration curve of a stream is a plot of discharge against the percent time the flow was equalled or exceeded. The discharge at any percentage of probability represents the flow magnitude in an average year that can be expected to be equalled or exceeded.

Availability of Surface Water for Mathbaria Paurashava is as follows:

Nearby River/ Khal: Baleswar
Dependable Flow: 2254.5 m^3/ sec
Exploitable Flow: 1352.7 m^3/ sec
Availability: 116,873 m^3/ day
Availability duration : 12 months

Exploitable Flow means 60% of the dependable follow of the river or Khal, keeping remaining 40% for environmental purposes.

5.3 *Normal probability plot using Weibull formula*

Probability plots are useful for visually revealing the character of a data set. Plots are very convenient and effective way to observe what the data look like and to evaluate if the fitted distributions are consistent with the data. In preparing the probability plots it is required to assign probability to each observation in a data series by using a “plotting position” formula. Several plotting position formulas are available as shown Table 2.

Table 2. Plotting position formulas

Method	Equation
California	(m/n)
Hazen	(m-0.5)/n
Beard	1 - (0.5)1/n
Weibull	(m/n+1)
Chegodayev	(m-0.3/(n+0.4)
Blom	(m-3/8/)/(n+1/4)
Tukey	(3m-1/3n+1)

This study adopted the *Weibull* flow-duration method for dependable flow analysis. In this method, the desired value (i.e. dependable flow) is obtained by ranking the daily flows in descending order and assigning each with an exceedance probability of flow using the statistical equation given below:

$$P = \frac{m}{n+1} \qquad (1)$$

Where ***m*** stands for the rank number from 1 to **n** and **n** is the total number of ranked flows. This method was chosen due for its simplicity and easy adaptability to computers.

5.4 *Dependable flow analysis*

Dependable flows have been computed for year round analyses for the period of 1986 to 2009 for Mathbaria at chainage 101,625m of the Baleswar River. Year round dependable flows are shown in Table 3 and the flow-duration curve of dependable flow is given in Figure 3.

Table 3. Dependable flows of the Baleswar River at Mathbaria

Location	River Name	Dependable flow for the dry seasons (m^3/s)		
		50%	80%	90%
Mathbaria	Baleswar	5194.3	2254.5	1210.4

Figure 3. Flow-Duration Curve of dependable flows of the Baleswar River at Mathbaria

Considering the assessment for a surface water treatment plant of $0.069m^3/s$, which is about 0.0009% of the 80% dependable flow:

Surface water withdrawal for Mathbaria Paurashava = $0.069m^3/s$
80% dependable flow at Mathbaria = $2254.5m^3/s$
Available flow after withdrawal = $2254.23m^3/s$
Environment requirement (40% of 80% dependable flow) = $901.8m^3/s$

5.5 *Water quality analysis*

Water quality assessment was carried out based upon primary water sampling data collection session carried out at the selected location on Masua Khal at Mathbaria Paurashava which carries water from the Baleswar River. The sampling sessions were carried out twice during the project period of phase-I at 12:00 noon. The first sampling mission was carried out in the month of June 2010 i.e. during the pre-monsoon period when the water quality is at the most deteriorated level; however, there were no flow in the river at the time due to which samples were not taken. The second mission was carried out in the month of September 2010 i.e. during the monsoon period when the water quality is at a much better state.

Table 4. Measured water quality of the Masua Khal at Mathbaria

Sl.	Parameter	Unit	Allowable Limit of River Water for Treatment	Allowable Limit for Drinking Water	Measured Value Pre-Monsoon	Measured Value Monsoon
1	pH	-	6.5-8.5	6.5-8.5	6.97	6.45
2	DO	mg/l	>6	6	7.27	8.31
3	BOD5	mg/l	<2	0.2	16	8
4	COD	mg/l	NA	4	40	28
5	NH3-N	mg/l	NA	0.5 total	1.30	0.26
6	NH4-N	mg/l	NA		1.38	0.27
7	NO3-N	mg/l	NA	10	13.5	2.8
8	TDS	mg/l	NA	1000	542	196
9	TSS	mg/l	NA	10	5.3	24
10	PO4-P	mg/l	NA	6	1.75	0.26
11	Cr Total	Mg/l	NA	0.05	0.0030	0.006
12	Cd	mg/l	NA	0.005	0.0001	0.004
13	Pb	mg/l	NA	0.05	0.0011	0.002
14	Cl-	mg/l	NA	150-600 (1000 at coasts)	220	74
15	SO4-S	mg/l	NA	400	22	4
16	Hg	mg/l	NA	0.001	0.0009	<0.00015

***** *NA: Not Applicable; Reference: EQS for Bangladesh, Department of Environment (DOE) July 1991*

The rainfall and consequently the river stage and discharge remained quite low during at the initial stage of the year 2010 and thereby the pre-monsoon water quality sampling was done in June 2010. The monsoon water quality sampling was deferred to the month of September when there was significant flooding in the river. The samples were duly tested at the DPHE Central Laboratory. The test results thus obtained is presented below in Table 4.

It is observed from the test results that water quality Masua Khal at Mathbaria is not within allowable limit for number of parameters such as BOD_5, COD, NO_3 and Ammonia levels for monsoon season and Ammonia from Pre-Monsoon season. Therefore, Masua Khal though located at a convenient location of Mathbaria Paurashava, is not at all suitable as a source of water supply for the Paurashava. Rather, water quality of the Baleswar River is reported to be good enough for treatment and water availability is also sufficient as analyzed in previous section. However, further sampling needs to be carried out to establish this fact for conclusive evidence.

5.6 *Findings of surface water source assessment*

From different studies, the following information regarding water supply development has been compiled for Mathbaria Paurashava.

a) Predicted population and Demand of drinking water:

Projected Population, 2010	19,818
Projected Population, 2025	31,810
Projected Population, 2040	49,593
Water Demand 2025	1590m3/day
Water Demand 2040	5330m3/day

b) Availability from Surface Water:

Nearby River/ Khal	Baleswar River
Dependable Flow	2254.5m^3/s
Exploitable Flow	1352.7m^3/s
Availability	116,873$m^{3/}$day
Availability duration	12 months

From the analysis and findings, it appears that the Baleswar River located at a distance of 9kms of Mathbaria seem to be a dependable source for safe drinking water for Mathbaria Paurashava. However water quality checking has to be carried out to establish and clarify this decision. It is also reported that the river water is saline due to tidal incursion for quite sometimes.

6 GROUNDWATER MODELING

In general, groundwater is a more acceptable source than surface water since groundwater quality is normally in the range of potable water quality and treatment cost is also minimal. In connection with this project, detailed study has been carried out for assessment of groundwater source. This groundwater study component has two major sub-components- a) Hydro-geological studies and b) Groundwater modeling.

Hydro-geological study has been carried out to understand the regional hydro-geological setting, local hydrogeology and hydro-stratigraphy, delineation of the aquifer system, groundwater level situation and groundwater quality of the area. The groundwater model has been developed to understand the groundwater flow dynamics and to assess the groundwater resources at the present condition as well as groundwater resources at future development scenarios.

6.1 *Lithological characterization and aquifer system delineation*

For groundwater modeling purpose, extensive secondary data has been used to understand the aquifer properties at Mathbaria and near Paurashava areas. Hydro-stratigraphic section reveals that top most impervious layer varies from 5m to 25m. Below the top most impervious layer a layer of aquitard exists. The thickness of this layer varies from 15m to 45m. Below this layer an impervious layer of 15m to 90m exists. Between the above two layers a fine sand dominant aquifer is found, the thickness of which varies from 5m to 50m. Below the above layers, in the Gulishakhali area (GL7958001) an aquifer layer of 5m to 40m thickness exists. A continues aquifer layer of thickness 20m to 100m lies. This aquifer layers extends from 170m to 200m in the Gulishakhali area (GL7958001) and 110m to 210m in Phuljhuri area (GL7958005) side. This aquifer layer is overlain by a 25m thick aquitard layer in the south side and the Phuljhuri area (GL7958005) side of this aquifer is overlain by 5m to 50m thick fine sand dominant aquifer. Another dipper aquifer exists from 230m to 310m throughout the area. But in the Phuljhuri area (GL7958005) a lens of 15m thick aquiclude penetrated this aquifer. This aquifer is separated by 5m to 60m thick aquiclude. Above this aquiclude a thin clay lens exists in the Gulishakhali area (GL7958001). In this section the upper aquifer is bounded by impervious layer indicates the nature of the aquifer is confined. If water quality is satisfactory the aquifer can be developed. During the field visited the local peoples and Paurashava authorities inform that water quality of Sener Tikikata area are suitable for drinking.

6.2 *Groundwater modeling*

The main purpose of the study is to evaluate the overall water resources of the study area for an efficient planning and management of resources. For assessment and development of groundwater resources a mathematical model describing the conditions in the unsaturated and saturated zone of the subsurface together with rainfall, overland flow, evapotranspiration and the condition of flow in the river, are required.

The MIKE 11 hydrodynamic module uses an implicit, finite difference scheme for the computation of unsteady flows in rivers and estuaries. The module can describe sub-critical as well as supercritical flow conditions through a numerical scheme and simulate main hydraulic processes i.e. flow, velocity and water level in the river (MIKE11- DHI 2002). MIKE SHE is a comprehensive mathematical modeling system that covers the entire land-based hydrological cycle. It is a finite difference model, which solves systems of equations describing the major flow and related processes in the hydrological system and simulates surface flow, infiltration, flow through the unsaturated zone, evapo-transpiration and groundwater flow (MIKE SHE- DHI 2002).

The MIKE 11 and MIKE SHE models are interactively linked and capable of producing water balance and change of storages in the form of groundwater recharge/discharge and fluctuations in water tables.

The groundwater model has been developed to understand the groundwater flow dynamics and to assess the groundwater resources at the present condition as well as groundwater resources at future development scenarios. Model has been developed covering entire study area with grids size of 1000m×1000m squares.

The model has been calibrated using data for the period 1997 to 2005. In order to get further reliability, calibrated model has also been validated using the recent data of 2006-2009. Finally taking the calibrated and validated parameters the model has been applied for various development scenarios by assigning future abstractions. The first step in the procedure of modeling is the development of a conceptual model of the problem. The conceptual model consists of a set of assumptions that reduce the real problem and the real domain to simplified versions that are acceptable in view of the objectives of the modeling and of the associated management problem.

The model area has been selected based on the present and probable future extension of the different Paurashavas for future domestic water supply project. The area is bounded by Tentulia river on the East and Kacha River on the West and District boundary of Shariatpur on the North and part of the Barguna District on the south as shown in Figure 3.2. The model area spreads over 34 Upazilas of Barguna, Barisal, Bhola, Chandpur, Jhalokati, Madaripur, Patuakhali, Pirojpur, and Shariatpur districts.

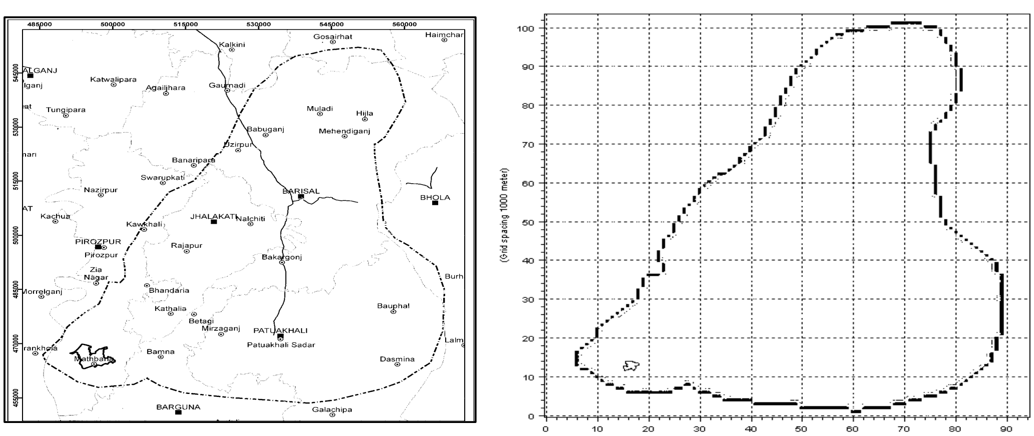

Figure 4. Study area divided into 1000mX1000m grid

Based on hydrological condition, existing crop coverage, irrigation demand etc. the total water balance of the model area has been analyzed through modeling and thus the groundwater resource assessment has been performed. The availability of groundwater resources within the 6 m and 7 m depths are estimated based on available saturated thickness up to 6 m and 7 m depths multiplied by specific yield of the area in question (volume of water = area x $\Delta h \times SY$, where Δh is the saturated thickness within 6 m and 7 m depths). Following this procedure, model grid wise groundwater availability has been estimated. From data analysis it appears that only 2 geological layers exist within 7 m depth. Saturated thicknesses of these 2 layers have been calculated based on following considerations:

– Case-1: if thickness of 1st layer exceeds 6 m or 7 m, entire saturated thickness lies only in 1st layer.
– Case-2: if thickness of 1st layer remains above the groundwater table, entire saturated thickness lies only in 2nd layer.
– Case-3: if case 1 & case 2 do not occur, then saturated thickness lies in both 1st and 2nd layers. To find out the thickness of 1st layer within the saturated thickness, simply depth of water table is subtracted from the thickness of 1st layer. Now, to find out the thickness of 2nd layer within the saturated thickness, part of 1st layer within the saturated thickness is subtracted from the entire saturated thickness.

Saturated thickness of 1st and 2nd layers are multiplied by the corresponding specific yield values and summed up to get the depth of water availability of a grid. Availability in volumes is calculated by multiplying the depth of water availability by the area of the grid. Finally, water availability is estimated based on number of grids that lie within the area. Finally, groundwater availability has been estimated for 2 different depths. The study reveals that groundwater resources for Mathbaria Paurashava under 2 different depths are 14.85 Mm^3 for 6m depths and 17.45 Mm^3 for 7m depths respectively.

In general for the unconfined aquifer the depth of 6m and 7m is used to calculate the available resources within the limit of suction mode pump. Due to the long term sustainability of the groundwater resources for safe water supply as per the required quantity, the deeper aquifer found more acceptable. Considering the above facts, the aquifer storage volume has been calculated based on the recharge to the deeper aquifer multiplied by the aquifer catchment area.

6.3 *Water quality analysis*

As detail analysis result of deeper groundwater sample of Mathbaria test tube well under this study is not available, groundwater quality analysis data of 3 groundwater samples collected from 3 (three) piezometric wells of depth 60.07, 152.44 and 280.84 meters of Tushkhali mouza owned by BWDB is given below. From the water quality analysis it has been observed that, for ions like Cl-, Na, K and Ca; the test value has been found as excess of allowable value. Thus without treatment water supply is not possible. The salinity value is well over the acceptable limit thus practically cancel out this source as a potential one.

Table 5. Analyzed parameters with concentrations of 3 test wells

Well ID	Ca	Mg	Na	Mn	Fe	B	Cl-	CO2	HCO3	SO4	F	CO3	Hardness	NO3	K
7958113	61.6	16.78	117.65	0.28	0.89	0.0	181.0	162.0	242.00	24.84	0.27	0.0	154.0	0.38	0.9
7958112	99.2	38.09	5454.15	0.11	0.70	0.0	8391.0	238.0	779.00	0.91	0.33	1.1	248.0	1.40	27.0
7958111	231.2	9.17	5607.55	0.21	0.14	0.5	8627.0	299.0	751.00	1.08	0.29	151.0	578.0	9.92	22.7
*WHO	-	-	200.00	.10	0.30	0.3	250.0	-	-	250.0	1.50	-	-	50.00	-
Bangladesh	75.0	30~35	200.00	.10	0.3-1.0	1.0	150-600	-	-	400.0	1.00	-	200-500	10.00	12.00

*Guidelines for Drinking Water Quality, World Health Organization, Geneva, 2008.

6.4 *Findings of groundwater source assessment*

From the hydrographs and water balance for different periods the following overall conclusions can be drawn for Mathbaria Paurashava:

– The actual groundwater recharge is about 43mm which comes mostly from rainfall. As the groundwater level remains almost near to the land surface, most of the rainfall flows as overland flow and the recharge is less.
– In terms of water availability, in Mathbaria Paurashava area, 14.85 Mm^3 of water is available if we consider 6m depths where as 17.45 Mm^3 of water is available for 7m depths.
– From the hydrographs analysis for future condition it can be concluded that the groundwater tables will be in steady state condition after 24 months of starting pumping with a drawdown of approximately 1m in the production well.
– Groundwater contains excessive salinity, treatment of which is costly and almost impossible.

Therefore, groundwater in Mathbaria cannot be considered as a suitable source for water supply scheme due to water quality problem though sufficient quantity of water can be extracted..

7 PROVISION OF IMPOUNDING RESERVOIR

From the findings of surface water modeling and groundwater modeling, it is evident that both the water source is sufficient in quantity to meet the water demand in Mathbaria up to the year 2040. But both the sources suffer in water quality issue. Groundwater is not acceptable at all due to excessive salinity. Surface water source also have salinity problem for about two months. Therefore, an augmentation of water availability is proposed by constructing an impounding reservoir. The proposed reservoir will store fresh water for 3 months- March, April and May. Considering the storage duration, the water demand of the Paurashava, evaporation and seepage loss etc. the size of the reservoir has been computed approximately 670m×130m×6m. For the saline period, raw water will be conveyed from impounding reservoir to the water treatment plant and for the rest of the period it will be directed from the khal to the treatment plant. As The Baleswar River carries abundant water, water in Masua khal will be available always due to gravity flow from river to khal.

8 CONCLUSIONS

For the proposed water supply scheme in Mathbaria Paurashava, the projected water demand is computed as 5725m^3/day for the design year 2040. Mathematical modeling of both surface water and groundwater has been done to investigate the potential source for water supply. From the modeling results, it has been realized that both the sources have required amount of water. But surface water becomes saline for two to three months before monsoon and groundwater contains high level of salinity. So groundwater supply is not possible for Mathbaria. On the other hand, extraction of water from Baleswar or Masua khal for all year round is also unfeasible due to the salinity level augmentation in pre-monsoon period. Therefore, a provision for an impounding reservoir has been proposed for Mathbaria Paurashava for water supply during the period of excess salinity intrusion.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contribution of all team members of this project. Particularly, Mr. Monowar Ali, Project Direcor, Ground Water Management Project, DPHE is appreciated for his kind consent to the authors for this publication. the invaluable support of Mr. Emaduddin Ahmad, Team Leader, Comp-I, Mathematical Modelling for safe Drinking Water Source Identification, DPHE, Mr. S M Mahbubur Rahman, Director, Water Resources Planning Division, IWM and Mr. A.K.M Abdus Satter, Senior Pipe Network Modeler, Comp-I, Mathematical Modelling for safe Drinking Water Source Identification, DPHE will be remembered with gratitude. The authors are also thankful to colleagues of IWM- Mr. Goutam Chandra Mridha, Mr. Md. Zainal Abdin and Mr. Saad Siddique for their contribution in this particular assignment.

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