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Developing Conceptual Aquifer Geometry, Structural Geological Control and Possibility of Sea Water Intrusion in Cox's Bazar Area of Bangladesh

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Abstract: *The research work deals with the hydrogeological condition of Cox's Bazar area in Bangladesh. Most of the area is covered by northern part of Inani anticline. The structure is elongated, broad crest, steep flank, box-like and asymmetrical anticline. It is very hard to measure aquifer geometry of a complex geological area like Inani anticline. Hydrogeologically the study area broadly divided into two zones; Zone-1: Alluvium and Zone-2: Complex geology. From the analysis of the individual log and subsurface hydrostratigraphic sections, eight confined aquifer (Aquifer A, Aquifer B, Aquifer C, Aquifer D, Aquifer E, Aquifer F, Aquifer G and Aquifer H) and one unconfined aquifer (Aquifer O) observed in the Complex geology zone and the Alluvium zone in the study area respectively. The water tables in the confined aquifers are lies in high depth but in case of unconfined aquifer the water table lies near to the surface. From the structural geological condition and position of the aquifers, it is not possible to mixing sea water with groundwater from the western side of the study area where the Bay of Bengal is situated. The northern extension of the aquifers occurred in the area cut by the Bakkhali River channel. Although the area is structurally plunged and topography increase toward south, the major portion of the city area lies in the topographically low land near the Bakkhali River. If the fresh water from the aquifers is removed in the area by extensive pumping of water or sea level rises or cyclonic storm or tidal surges occur; sea water can be intruded into the zone.*

Key words: *Aquifer geometry, Complex geology, Unconfined aquifer, Confined aquifer, Saline water.*

I. Introduction

The study area lies in the north of the Cox's Bazar district. The area is about 32.92 km^2 and bounded by N 21º28′52″ to N 21º24′33″ latitudes and E 91º56′38″ to E 92º00′33″ longitudes, located 150 km south of Chittagong. The Chittagong-Tripura fold belt refers to as Eastern fold belt of Bengal Basin (Bakhtine, 1966) and Western fold belt of Arakan-Yoma Range (Reimann, 1993), considerate to be the youngest structural division of the western folded flank of the Indo-Burman Range. Most part of the Eastern fold belt is situated in the Chittagong and Chittagong Hill Tracts area. The study area is the continuation of Eastern fold belt and comprises large beach and coastal zone. Most of the area is covered by northern part of Inani structure (Fig. 1). The Inani structure is represented by NNW-SSE trending low hillocks attaining maximum 542 feet elevation above sea level. No research work has been carried out on the aquifer geometry and structural geological control of sea water intrusion of the Cox's Bazar area. The reports of other geological field of interest were found as broad regional scale. Cox's Bazar bearing the world's longest beach about 120 km long.

Millions of tourists visit the area for the beach beauty of the coastal zone, especially during Dry season. Now the population of the study area is about 2,51,063 (BBS, 2011) which increases the pressure on freshwater supply. Saline water of the Bay of Bengal in the west, brackish water of Maheshkhali Channel in the north and Bakkhali River in the east bounded the aquifers of the study area. If the fresh water of the aquifers is removed by extensive pumping of water, sea water can be intruded in the zone. The development of coastal zone depends upon the development of the deep aquifer. None of the classifications could well define the Cox's Bazar area. Therefore in this research, an effort has been made to prepare a simplified hydrogeologic map and cross-section of Cox's Bazar area which would give a generalized idea of the groundwater geometry and its development.

II. Methodology

The field work has been carried out in two stages. In the first stage, the field work has been carried out along the Kalatali road-cut section, Kalatali chara and Baro chara section. It was measured the attitude of the exposed beds, study about the lithology, structure and collected sample from the section of the study area. The maps have been drawn from the field observation and measurement of exposed bed of rock strata with the structural concept of the study area. The thickness of bed is calculated by the formula of Compton 1966 (Fig.1) and then it has been calculated aquifers and geological formations thickness.

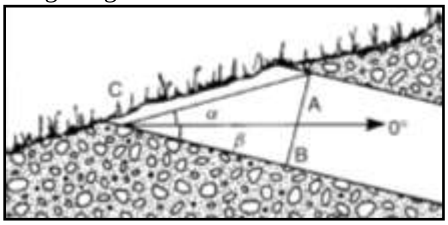


Fig. 1: Correcting for the true thickness of a bed. The stratigraphic thickness AB = AC sin (α + β).

In the second stage, the rock cuttings from the borehole observed and collected to understand subsurface lithology with depth during the field work. There are also collected the data of pumping well, borehole and observation well. The cross sections are drawing along two line of the study area and trying to find out the 3 dimensional (3D) view of the area. The figures are drawing based on the conceptual data and some observational field work of the study area. The borehole data of Department of Public Health Engineering (DPHE) (BH-2, BH-3, BH-4 and BH-5) (DPHE, 2010) used to adjust the conceptual correction and adjustment. Also a BWDB (Bangladesh Water Development Board) running observation well (BH-1) borehole log collected during field work (Fig.3).

Data processing was done by using various computer software and statistical methods. Data collected from field, secondary data and generated data were processed by using ArcGIS 9.2 and Excel 2007. The 3D elevation map was prepared by using ArcGIS 9.2 obtained from SRTM (Shuttle Radar Topography Mission). Hydrostratigraphic cross-sections of the subsurface are drawn using bore-logs of the existing wells distribution all over the area. ArcGIS 9.2 is used to prepare these cross-sections. Lithologies are plotted in each of the boreholes which ultimately revealed the clear cross-sectional view of the subsurface hydrostratigraphy. The preparation of such sections is depended upon the borehole data collected from DPHE and BWDB.

III. Results And Discussions

The eastern Folded Belt of the Bengal Basin exposes mainly geosynclinals molasse sediments of Neogene age, comprising alternating shale, mudstone, siltstone and sandstone in varing proportions. This succession has been lithostratigraphically subdivided into Surma (Bhuban and Bokabil), Tipam and Dupi Tila Groups following the classification of Evans (1932). Most of Bangladesh is covered by Tertiary and Quaternary sedimentary deposits which thicken to the south, where they locally exceed 20,000 m in thickness (Curray, 1991). The strata are deltaic to shallow marine in the north, but become progressively more marine to the south (Alam, 1989). The most western and northern side of the study area is covered by Recent beach deposit. After Recent deposit Bokabil Formation found and covers the western side of the Cox’s Bazar city. Majority of the study area is covered by Tipam Fomation. In the east Girujan Clay and Dupi Tila Formation is covered as a narrow area in the surface geological map.

The deposits of the Inani Anticline have been divided into Middle and Upper Boka Bil, Tipam Sandstone, Girujan Clay and Dupi Tila Formations. Inani is a narrow and elongated structure in which the Tipam Sandstone Formation is characterized by steep zone in both the flanks. Maximum 70° dip was recorded in the steep zone. In the crestal part the dip varies from 3° to 12°. The Tipam Sandstone Formation is unconformably underlain by the Boka Bil Formation in a gradual low dip. The oldest exposed rock is the Boka Bil Formation (BAPEX, 1980). From the field observation and measurement it has been found that the thickness of Dupi Tila Formation vary from 0 to about 300 m, Girujan Clay Formation vary from 70 m to 300 m and Tipam Sandstone Formation vary from 240 m to about 800 m. The thickness of the oldest exposed formation Upper Boka Bil and Middle Boka Bil is 70 m to 400 m and 60 to 110 m respectively.

Table 1: The stratigraphic succession of the Inani Hill Range (BAPEX 1980).

Age	Formation	Lithological Description
Mio-Pliocene?	Dupi Tila (DT)	Sandstone: Light, brownish, yellowish and whitish grey in color, medium to coarse grained, massive, ill sorted, highly porous, loose and friable, sedimentary pebbles like quartzite, siltstone etc. common.
Late Miocene	Girujan Clay (GC)	Bluish, earthy and whitish grey, soft and sticky;
Middle Miocene?	Tipam Sandstone (TS)	Light brownish, brownish and sometimes bluish grey, fine to medium grained, cross-bedded, ripple marked, moderately sorted and consolidated.
Early Miocene?	Upper Boka Bil (BB)	Shale: Bluish to earthy grey, thinly well laminated, moderately hard and compact, occasionally calcareous siltstone tabular concretion common.
	Middle Boka Bil (BB)	Alternating beds of sandstone and shale. Sandston: Bluish to brownish grey, fine grained to very fine grained, massive and cross-bedded, moderately consolidated, calcarious conglomeratic (occasionally fossiliferous) bed present. Shale: Bluish grey to grey, thinly well laminated, moderately hard and compact.

The evaluation of landforms and soils of the Cox's Bazar and adjoining areas in a part of the coastal region of the north–south trending fold belt of Bangladesh during the Late Quaternary Period (Khan *et al.*, 2005). Hydrostratigraphic cross-sections of the subsurface are drawn using bore-logs of the existing wells distribution all over the area. Two cross-sections of the subsurface are drawn taking sea level as the datum. At first the area divided into two broad zones; Zone-1: Alluvium and, Zone-2: Complex geology (Fig. 2).

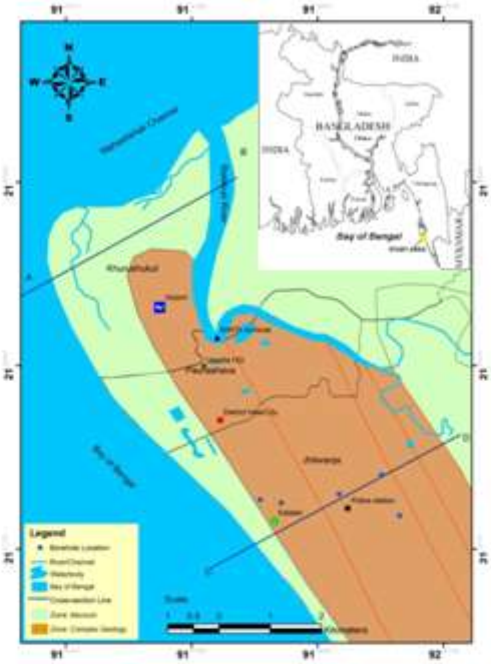


Fig. 2: The section line A-B and C-D, borehole, observation well and pumping well location map of the study area.

3.1 Aquifer Geometry

In the coastal area of Bangladesh, hydrogeological conditions vary considerably even within short distances. Transmissivities of the main aquifer in the coastal area range from 250 m^2/day to 10000 m^2/day with an average value of 1000 m^2/day. The storage capacity of the aquifer generally increases with depth with the increase in the grain size of aquifer materials. The entire area is underlain by thick water bearing formations of varying depths and the regional hydrogeology is very complex (Ahmed, 1996). Hydrostratigraphic sections are normally the best method of ascertaining the aquifer geometry, which is the lateral and vertical extension and depth of the aquifer. In all cross-sections nine different zones of distinct hydrostratigraphic unit are recognized from top to bottom (Fig.5 and Fig. 6). From the analysis of the individual logs and cross-section sections, there are found eight confined aquifer in the Complex geology zone and one unconfined aquifers in the Alluvium zones in the study area (Fig.5 and Fig. 6).

Unconfined aquifer:

1. Aquifer O

Confined aquifer:

2. Aquifer A
3. Aquifer B
4. Aquifer C
5. Aquifer D
6. Aquifer E
7. Aquifer F
8. Aquifer G
9. Aquifer H

Unconfined aquifer: The unconfined aquifer covers the large part in north and a narrow zone in west. It comprises the Aquifer O covered about 8.2 km^2 area of the study area (Calculated from Map) (Fig. 2).

Aquifer O: Aquifer O represents the unconfined aquifer in the study area. It covers northern and most western part of the area. Surface elevation in this part is maximum 5 m above sea level. It is mostly covered by Recent deposits. The Tertiary deposits found in the immediate below the recent deposits, lies about 6 to 15 m below from land surface. The water table elevation lies in the zone from 2 to 5 m from land surface. It is a shallow aquifer and this zone is favorable for shallow tubewells installation. There are found many shallow tube wells in this zone used as for drinking water, domestic supply and irrigation. From the schematic hydrostratigraphic section along A-B in the map (Fig. 3), it is shown the aquifer condition of the zone. In the northern side the aquifer bounded by saline water in the three sides. For the most western case the aquifer bounded by Bay of Bengal in the west.

Confined aquifer: It covers most of the area about 12.62 km^2 in the study area. It lies in the zone of Complex geology. From the schematic cross-section along C-D in the map (Fig. 4), it is found the subsurface picture of the aquifers. The eight confined aquifer identified in the study area and aquitards found above and below the aquifer with considerable thickness. The descriptions of the aquifers given blow-

Aquifer A: The aquifer lies about 100 m below the surface in the coastal area but the depth increases toward east for lies as part of the Inani anticline. The recharge area did not identified, may be next syncline of the Inani anticline. The thickness of the aquifer is about 50 m. from the borehole data it is composed of medium grained sand. About 10 and 200 m thick aquitards lies above and below the aquifer respectively. The aquifer is very suitable for the supply of drinking water.

Aquifer B: The aquifer lies about 20 to 25 m below the surface in the coastal area but the depth increases toward east. The recharge area did not identify. The thickness of the aquifer is about 10 m, from the borehole data it is composed of medium to fine grained sand. It is bounded by about 10 m thick aquitards above and below. The aquifer is suitable for the supply of drinking water.

Aquifer C: The recharge area is large and may be connected with the unconfined aquifer lies in the zone. The top and bottom of the aquifer bounded by about 8 m and 10 m thick aquitards respectively. The recharge area may be connected with the beach. It lies in the eastern flank of the Inani anticline. The aquifer lies obliquely with 5º angle of bed and increase dipping for the nature of the anticline.

Aquifer D: This aquifer lies in the eastern flank of Inani anticline in the study area. The recharge area is about 2.3 km^2 in the study area and it is inclined toward east about 8º to 25º, the dip increased eastward. The thickness is about 85 m. This aquifer is the part of Upper Bokabil Formation of the Inani structure. The groundwater table lies about 20 to 25 m below surface. This aquifer is not suitable for shallow wells development. This aquifer is most favorable for the supply of drinking water. The top and bottom of the aquifer is bounded by thick aquitards about 54 m and 8 m respectively.

Aquifer E: The recharge area covers about 4.72 km^2 in the study area and is the part of Tipam Formation. The thickness of the aquifer calculated is about 415 m; it is inclined toward east about 17 º to 40 º, the dip increased eastward. The top and bottom of the aquifer is bounded by 54 m and 58 m thick aquitards respectively. Majority of peoples are depended on this aquifer for their daily uses for drinking water, irrigation and supply water.

Aquifer F: It is the small aquifer about 176 m thick and top and bottom is bounded by thick aquitards about 58 m and 18 m respectively. The recharge area covers about 1.16 km^2 in the study area and the groundwater table lies about 10 to 15 m below surface. This aquifer is not suitable for shallow tubewells development.

Aquifer G: The aquifer is small rather than other in the study area about 63 m thick and top and bottom is bounded by thick aquitards about 118 m and 122 m respectively. It lies in the Girujan Clay Formations of the eastern flank of Inani anticline. The recharge area is small and covers about 0.37 km^2 in the study area and the groundwater table lies about 15 to 20 m below surface. This aquifer is not suitable for shallow tubewells development.

Aquifer H: It is very important aquifer in the area. It lies in the Dupi Tila Formation and covers large area. This aquifer is very suitable for shallow and deep tubewells development. The base of the aquifer is bounded by thick Girujan Clay Formation. Majority of peoples are depended on this aquifer for their daily uses for drinking water, irrigation and supply water.

Table-2: Summary of aquifer geometry of the study area:

Name	Aquifer Types	Depth of water table (m)	Thickness(m)	Bed Inclination (º)	Recharge area (km^2)	Aquifer development potential
Aquifer O	Unconfined	2-7	15-20	-	8.2	Shallow and deep
Aquifer A	Confined	-	50	5 º	-	Deep
Aquifer B	Confined	-	10	5 º	-	Deep
Aquifer C	Confined	-	-	5 º-10 º	-	Deep
Aquifer D	Confined	20-25	85	8 º-25 º	2.3	Deep
Aquifer E	Confined	20-25	415	17 º-40 º	4.72	Deep
Aquifer F	Confined	10-15	176	45 º	1.16	Deep
Aquifer G	Confined	15-20	63	45 º	0.37	Deep
Aquifer H	Confined	5-7		10 º	4.07	Deep

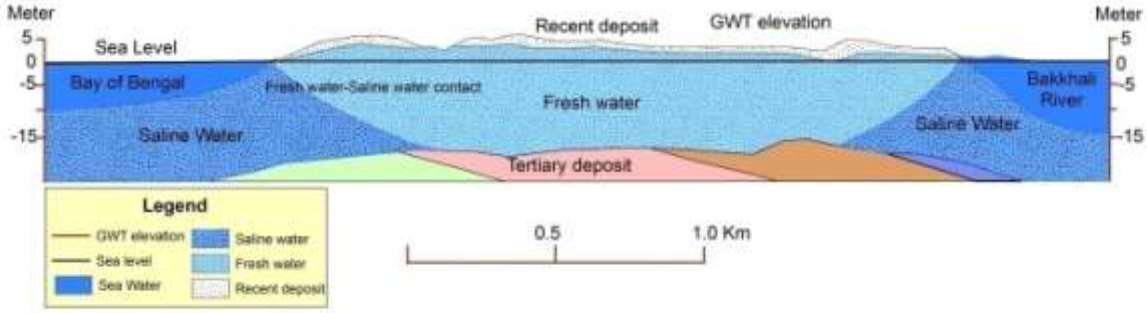


Fig. 3: Hydrostratigraphic section along the line A-B of Fig. 1.

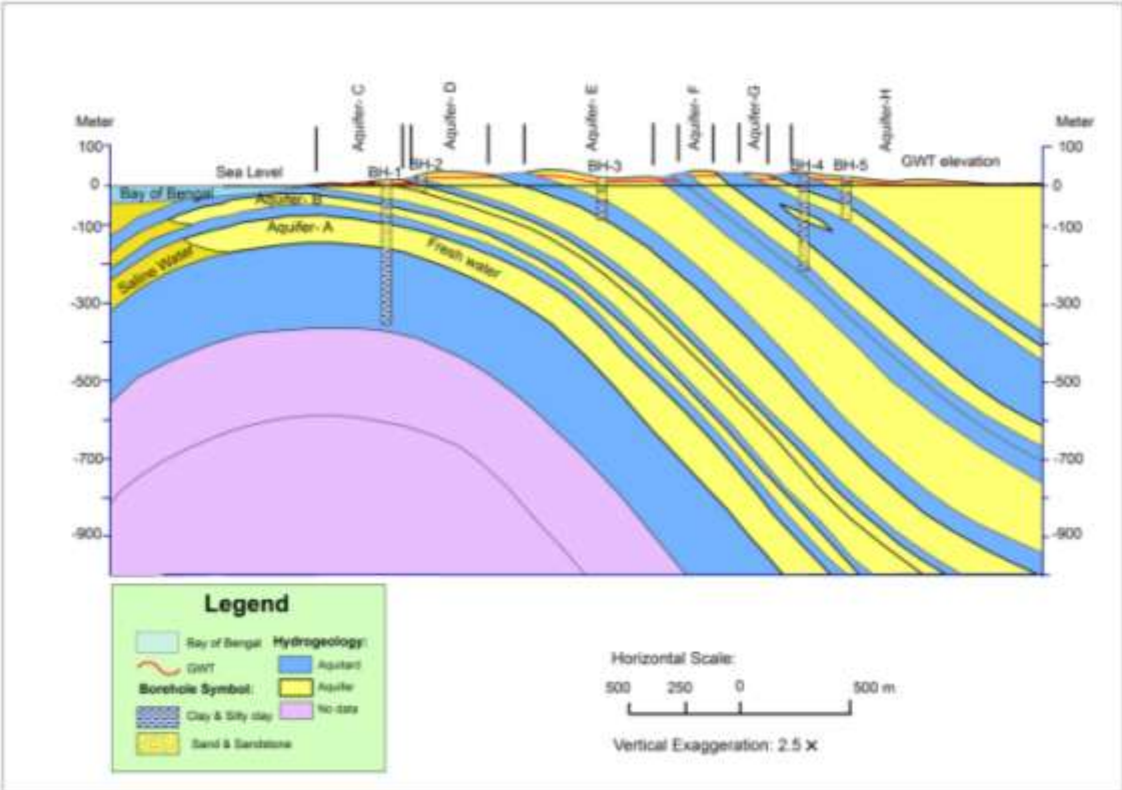


Fig. 4: Hydrostratigraphic section along line C-D of Fig. 1 with position of borehole and lithology.

From the analysis of the individual logs and cross-section sections, there are found eight confined aquifers (Aquifer-A, Aquifer- B, Aquifer-C, Aquifer-D, Aquifer-E, Aquifer-F, Aquifer-G & Aquifer-H) in the Complex geology zone and one unconfined aquifer (Aquifer-O) in the Alluvium zone (Fig 5 and Fig 6). The unconfined aquifer covers the large part in north and a narrow zone in west composed by sand of Recent deposits (Fig. 3). The sands are loose and friable. The aquifers occurred in the area mostly confined and covered large part of the area. They lie in the zone of Complex geology in the east, middle, west and south of the area. The recharge area of the aquifers opened to the surface in the zone. Most of the aquifers are composed of sand with moderate to high compaction, as a result the amounts of recharge are low and the GWT lies highly below the surface.

3.2. Structural Geological Control on Sea Water Intrusions

In general, the groundwater table mimics the surface topography, and groundwater flow is from the point of higher hydraulic head to the point of lower head, which, in a general sense, corresponds with the slope of the land surface. It is well known that the geologic process of erosion that leads to formation of stream valleys and inter-mountain divides also results development of stress-relief joints (fractures) in rocks (Domenico and Schwartz, 1990). The study area is covered by northern part of Inani anticline. Inani anticline is elongated, broad crest, steep flank, box-like and asymmetrical anticline. It is characterized by monotonous alternation of arenaceous and argillaceous beds with subordinate intra-formational conglomerates in the older exposed sequence. The entire western flank has been washed away by the sea except a segment of Middle Bokabil Formation in the axial part (BAPEX, 1980).

This formation is composed of shale and sandstone. The shale act as a barrier of sea water intrusion in the axial region lies west of the study area. From the Fig. 5 and Fig.6, it is shown that Aquifer A and Aquifer B lies below the shale layer, which prevents sea water for direct mixing with groundwater. The contact of saline water and freshwater are lies in the western flank of the anticline. Although the inclination bed only vary from 5º-10º in the coastal region, it is not possible to sea water intrusion in the region directly. In the study area the southern portion is topographically highly elevated than the northern portion. The intrusion of seawater in the coastal aquifers will be certainly affected by the presence of constant head boundary conditions (Das and Datt 2001). So the groundwater flows toward the north from south within the aquifers. The northern extensions of the aquifers meet to the Bakkhali River in the north and the city is situated besides the river and also the city area lies in the topographically low area. So, the saline water can be intruded from the Bakkhali estuary, if withdrawn of groundwater exceeds the recharge of the aquifer.

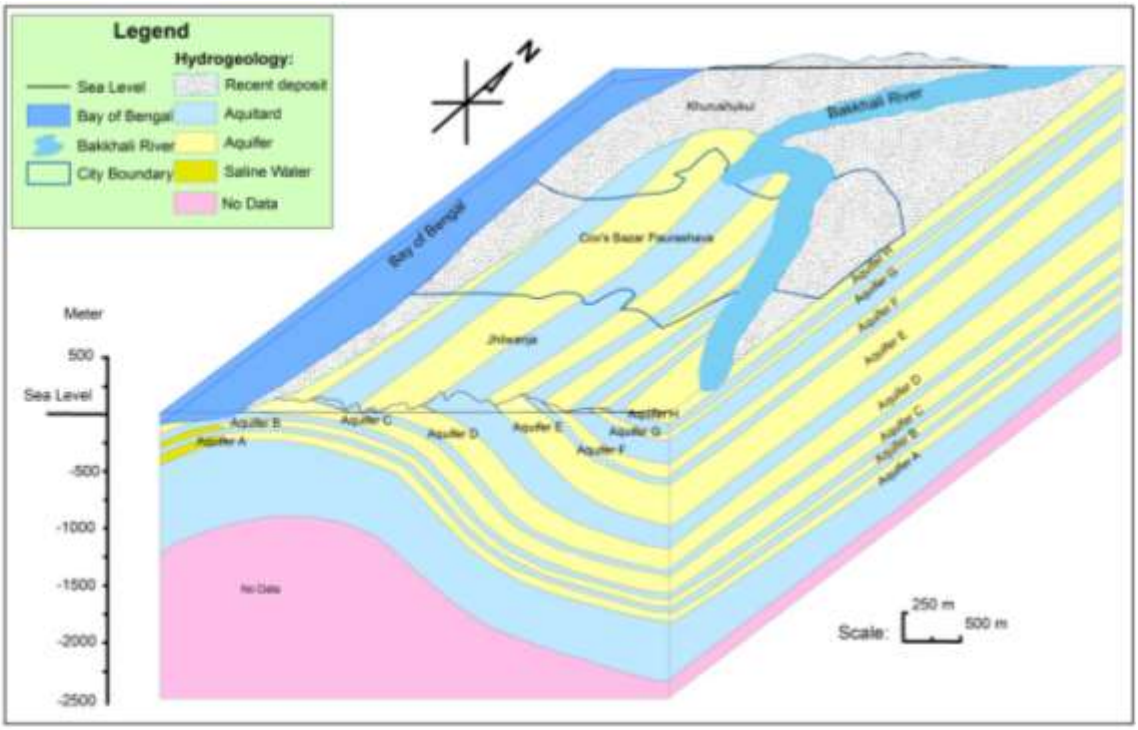


Fig. 5: 3D hydrostratigraphic map and aquifer system of the study area.

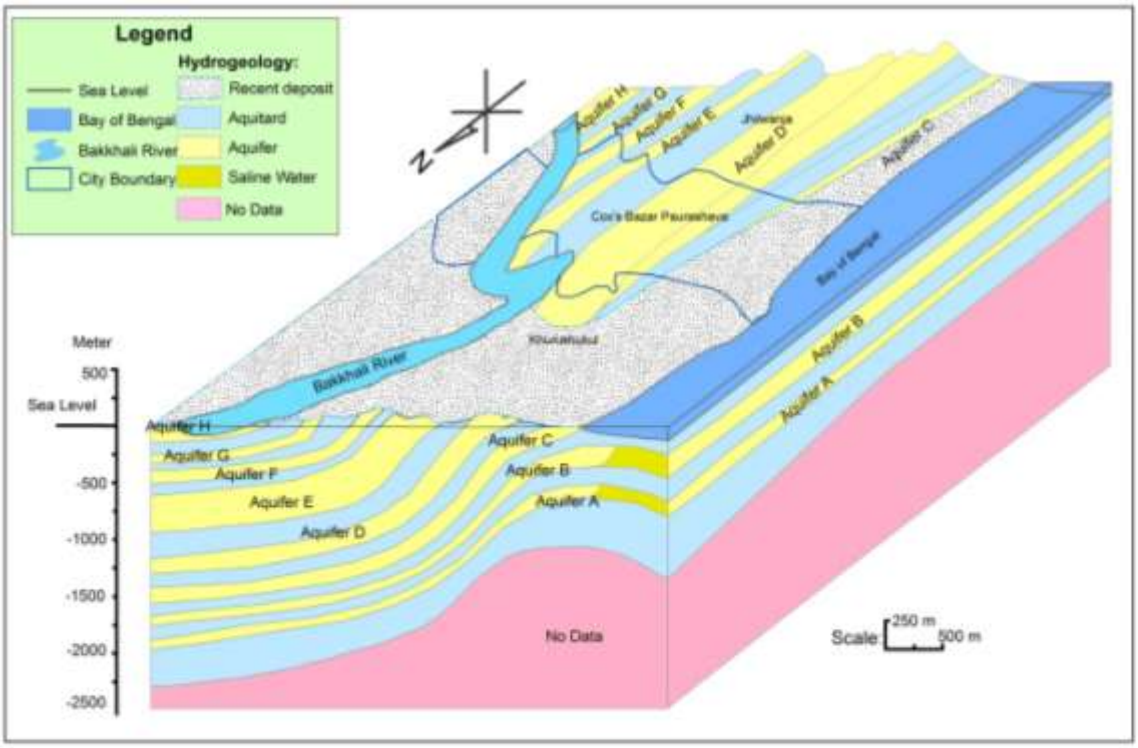
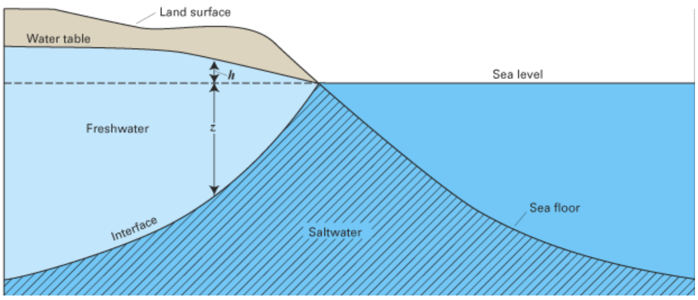


Fig. 6: 3D hydrostratigraphic map and aquifer system of the study area.

3.3. Possibility of Probable Sea Water Intrusion

Freshwater is slightly less dense (lighter) than saltwater, and it tends to float on top of the saltwater when both fluids are present in an aquifer. The relationship based on the density difference between saltwater and freshwater is used to estimate the depth to saltwater based on the thickness of the freshwater zone above sea level. The relationship is known as the Ghyben-Herzberg relation (Fig. 7) (Rahman & Bhattacharya, 2006).



Z=40h, h= Water level above sea level, Z= Thickness of freshwater below sea level.

Fig. 7: Schematic image showing the Ghyben-Herzberg relation.

Structurally it is not possible for sea water intrusion in the underground aquifer towards the east side of the city where the Bay of Bengal is situated. But there have possibility to sea water intrusion in Aquifer C and Aquifer E towards the north side of the city where Bakkhali River recharging the Aquifers. The salinity intrusion is a time varying event and with a minimum during the monsoon (June-October) when river discharge displaces the salinity front seaward in estuaries and floodplains. In winter season, when the water table shows minimum groundwater elevation, according to Ghyben-Herzberg relation, seawater moves through aquifer towards inland and the aquifer water become diluted and contaminated. The salinity front moves inland from the month of November due to the reduction of fresh water flows. So, the saline water intrusion can occur in the northern and north-eastern side in dry season for lack of recharge water. In the western zone the sea water intrusion can occur, if sea level rises or by the storm, surge effect. Moreover, in winter season when the production well start, water level drop far below the static water level due to aquifer and well loss, the obvious cause is the upward radial flow of the bottom water towards the strainer of the well to full fill the drawdown cone of depression and thus contamination of groundwater might be occurred in the study area.

Moreover, the time required for saltwater to move through an aquifer and reach a pumping well can be quite long. Depending on the location and lateral width of the transition zone, many years may pass before a well that is unaffected by saltwater intrusion suddenly may become contaminated (Kumar, 2006). If sudden contamination occurs, it can be dangerous for the people of the study area. Bangladesh standard for groundwater salinity is 600 mg Chloride per liter. As this value is widely exceeded in coastal areas, a more practical level of 1000 mg/l of Chloride has been suggested. This would approximately correspond to a threshold of 2 dS/m (1000mg/l Chloride solution generates EC of 1.5 to 2 dS/m) and a threshold level for surface water salinity and soil salinity is 5 dS/m and 4 dS/m (deci-Siemen per meter at 20-30 ºC) respectively. The salinity value (dS/m) of soil and surface water of the study area is more than 15 and 05-10 respectively where for ground water the value is less than 01. Besides this the average tidal fluctuation over the year is more than 02 m in the study area (PDO-ICZMP, 2003).

IV. Conclusion

The confined aquifers occur in the zone are not suitable for shallow water developments. The water tables in the confined aquifers are lies to the high depth but in unconfined aquifer the water table lies near to the surface. The unconfined aquifer is suitable for both shallow and deep aquifer development and the confined aquifer are only favorable for deep aquifer development. The depth and thickness of the aquifer are very important in designing tubewells. The depth is a factor, which determines whether the aquifer can be economically reached or not. The salinity value of soil and surface water shows extreme dangerous condition for the study area, but the groundwater still not contaminated with saline water. The ground water is the only source of drinking and irrigation water of the study area. Because of the structural condition, the saline water cannot contaminate from west side of the city but in the north side the aquifers are open to the brackish water. If the removal of ground water increases, the contamination can occur from the north side. So it need to consideration about extensive pumping from the aquifer or different methods can be applied to stop the intrusion of saline or brackish water in the north of the city. Also need to develop the zone of freshwater resource of surface water or need to find new source of fresh water.

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References

[1]. Bakhtine, M. I., *Major Tectonic feature in Pakistan*, Part II, Eastern Province, Science and Indusrty, *4(2)*, 1996, 89-100.
[2]. Riemann, K.U., *Geology of Bangladesh*; Gubruder-Bornfraeger, Berlin, Germany, 1993, 159p.
[3]. BBS, Community Report, *Bangladesh Population and Housing Census 2011*, Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, 2014, 57-88.
[4]. Compton, R.R. Manual of Field Geology. 2nd edn, New York, Wiley, 1966.
[5]. DPHE-JICA, Geological Log Record, Cox's Bazar Sadar Area, Aquifer Databse Inventory Program, Department of Public Health Engineering, DPHE Groundwater Circle, Dhaka,2010.
[6]. Khan, M.S.H., Parkash, B., and Kumar, S., *Soil-Land form development of a part of the fold belt along the eastern coast of Bangladesh.*, 2005.
[7]. Evans, P., *Tertiary succession in Assam*, Trans. Min. Geol. Ins., India, *5*, 1932, 80-96.
[8]. Curray, J.R., *Geological history of the Bengal geosynclines*, Journal of Association of Exploration Geophysicists XII, 1991, 209–211.
[9]. Alam, M., *Geology and depositional history of Cenozoic sediments of the Bengal Basin of Bangladesh*. Palaeogeography, Palaeoclimatology, Palaeoecology, *69*, 1989, 125–139.
[10]. BAPEX, *A report on Inani-Maiskhali anticlines, Cox's Bazar*, Bangladesh Petroleum Exploration and Production Co. Ltd., Dhaka (Unpublished), 1980.
[11]. Ahmed, F., *Coastal water supply in Bangladesh, Reaching the Unchanged: Challenges For The 21st Century*, 22nd WEDC Conference, New Delhi, India, 1996
[12]. Domenico, P.A., and Schwartz, F.W., Physical and Chemical Hydrogeology, Jobn Wiley & Sons, Inc., 1990.
[13]. Das, A. and Datt, B., Simulation of seawater intrusion in coastal aquifers: Some typical responses, Sadhana, India, 26(4), 2001, 317–352
[14]. Rahman, M.M. and Bhattacharya, A.K., Salinity Intrusion and its Management Aspects in Bangladesh, Journal of Environmental Hydrogeology, 14, 2006, 2-6.
[15]. Kumar, C.P., Management of Groundwater in Salt water Ingress Coastal Aquifers, National Institute of Hydrology Roorkee – 247667 (Uttaranchal), 2006.
[16]. PDO-ICZMP, Delineation of the Coastal Zone, Management Plan, Ministry of Water Resources, Government of Bangladesh, Dhaka, 2003.