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Vulnerability Assessment of Northern Side Open Pit Mining, Barapukuria Coal Field, Bangladesh

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Abstract-- **Along with the positive correlation of per capita energy consumption and per capita gross national product (GNP), Bangladesh appeared to have become permanently locked in energy sectors. Poor decision making on long-term energy-economic prospects and mostly underutilized projects due to lack of implementation schedule synchronization bring the country's status on the verge of its energy situation. While the numbers are approximate, recent estimates affirm that the reserve of gas will or may be exhausted within 10 years; additionally the other alternative sources of energy are neither adequate nor varied yet, however the firm decision has been taken up by some skilled people to perk up the mining sectors regardless of the dreadful conditions of ambiance. As consequences, the authority of BCMCL, own mining company of Petrobangla, has decided to expand the ambit of mine towards the Northern side with an admissible limit of recovery. Conversely, the aberrant change of geology may abstruse the advanced mining operation, even though, the biggest worst is the head to head contact of the major UDT aquifer and Permian coal deposit towards the Northern side. The aquifer varies from 90 to 124m in thickness with NE-SW directional flow. This article boils down to the major geological obstacles of mining progress through a number of 3D modeling and counsels how to remediate this difficulty. Dewatering process with an accurate limit of discharges can act as a conjurer to controlling the water pressure and handling discharges in a proper manner in terms of convenience of mining operation and nature is one of the priorities among some issues.**

Key Terms-- **Northern And Southern Sub-Crop Area, Qa Program, 3d Modeling, Dewatering, Artificial Recharge**

I. INTRODUCTION

Bangladesh achieved her status as coal resourceful nation after the first discovery of the Gondwana basin on an immense extent in 1962. Having an estimated reserve of about 3565 million metric tons, the country preside over five coal fields [1], whilst all of those are situated at the NW part of Bangladesh. Unfortunately considering the geological, social and economical repressions, the country is leading with only one coal mine which is Barapukuria coal mine.

Barapukuria coal field is situated in the Dinajpur District, within 88˚ 57' 15'' to 88˚ 58' 56'' E longitudes and 25˚ 34' 20'' to 25˚ 32' 47'' N latitude geographical co-ordinates (fig 1). The entire area of the coal field is about 5.25 km^2 but the extension possibility had been suggested towards the south within 1 to 1.5 km^2 (Wardell Armstrong, 1991).

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Within the VII coal seams, the Barapukuria coal field has been proved with 303 million tons demonstrated reserve of coal (Wardell Armstrong 1991). Depending on the positive feasibility study, Barapukuria started mining from only the thickest coal seam (coal seam VI) in the central portion by multi slice long-wall mining without backfilling method [2]. At present, the production work is carried out from the central part and the rest portions are totally untouched from mining activity. The progress of the coal field is not eye winked yet; additionally the annual production rate, nearly about 1 million tons, has gradually abating the economic-energy state of affairs. However, the acerbic truth behind the energy condition of the country is that the partial halt of the energy-economic growth is due to the improper energy use and partly due to isolating the other alternative energy sectors especially the coal sector.

Some researcher anticipated an allusion that extending the mine area will be the priority key for managing this situation; however, geological anomalous may abdicate the progression of the development and the production phase of the mine life.

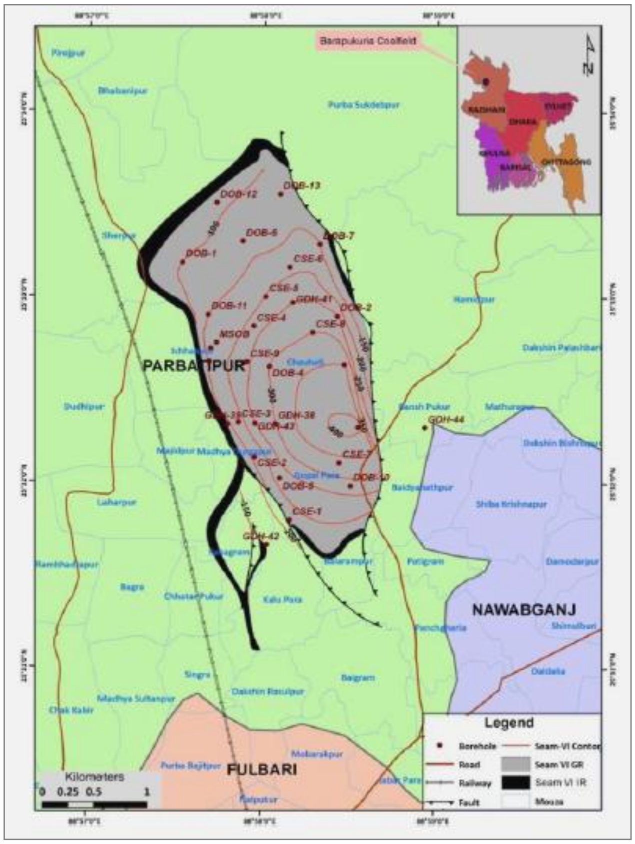

Fig 1: Location of Barapukuria coal field, NW Bangladesh

In that connection, this study sought to present some rigorous investigation on the Northern sub-crop area through 3D modeling rather to simulate the datasets for indicating the anomaly of the sub-surface and also trying to answer the research questions in the view of EIA of mining. The researcher questions are developed to narrow down the main focuses of the study and also to define the objectives of the work.

Researcher questions:

a. What is/are the geological anomalous that may hinder the mining progress in the N-side?
b. What is/are the farthest impacts?
c. How can it be controlled?
d. What is the probability of adverse effects after taking all the mining precautions?

II. Geology Of The Area

In perspective of Bangladesh, the Gondwana basins (Barapukuria, Phulbari, Jamalganj, Dighipara, Khalaspir, Naogaon) are situated within the Garo-Rajmahal gap of Bangladesh portion, locally known as Rangpur Saddle (Uddin and Islam, 1992, Bakr et al, 1996).

Structurally, the Barapukuria coal basin is a long, narrow and shallow asymmetrical synclinal basin that trends approximately N-S direction [3]. General axis of strike of the terrain is about N10^{0}W and the exhaustive portion is cut by numerous faults. On the basis of regional gravity data, the entire area is divided into two portions, one is the uplifted ridges (horsts) and another is the subsided basins (graben and half-graben) (Bakr et.al., 1996; Islam, 1993, 2002).

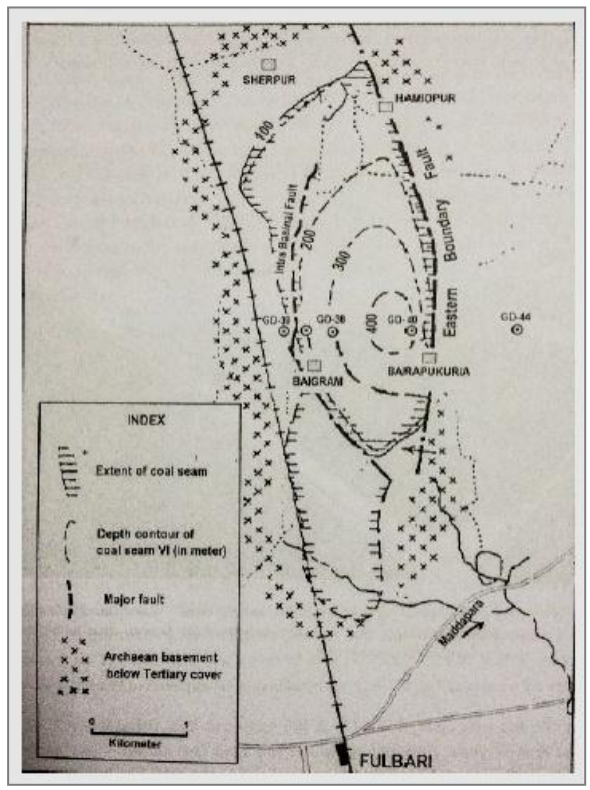

Fig 2: Detailed Geology of Barapukuria Coal Mine

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Stratigraphically, the area is consisted of four formations that follow the similar trends of dip. The coal bearing, Gondwana formation is just underlies the water bearing, Upper Dupitila formation, indicating an erosional or non-depositional major gap so that the coal seams are relatively close to the surface.

In Hydrological perspective, the coal mine area is much more complex and summarized as an incomplete syncline hydrologic unit. Having some recharge characteristics, the whole mine area is enclosed by two semi-confined aquifers (Dupitila and Gondwana) [4]. The stratigraphic succession of Barapukuria coal mine with hydrological characteristics is shown in table 1. Measuring the water levels in 22 boreholes W.A Company (1991) reveals that the upper and lower sand horizon of UDT aquifer are thick and its recharge condition is good; the ultimate results of these pumping tests are shown in table 2.

Table 1:
Stratigraphic Succession of Barapukuria coal mine

Age	Group	Formation	Member	Lithology	Thickness, m	Hydrology
Holocene		Alluvium		Silty clay	1.83	Aquiclude
Pleistocene		Barind Clay Residuum		Clay and sandy clay	10.36	Aquiclude
Pliocene		Dupi Tila	Upper	Sandstone, pebbly sandstone and clay/mudstone	126.82	Aquifer
			Lower	Sandstone, claystone and mudstone with silica and white clay		Aquiclude
Permian	Gondwana			Feldspathic sandstone, carbonaccous sandstone and shale, ferruginous sandstone, conglomertes, and coal beds.	457.32	Aquifer
Precambrian	Basement Complex			Diorite, granodiorite, quartzdiorite, granite, and diorite gneiss	14.32	Aquiclude

Table 2:
Results of pumping tests of Barapukuria (Source: Wardell Armstrong, 1991)

Parameters		Estimated value
Average Transmissivity		1200 m^2/day
Specific Yield		25-30 %
Storage Co-Efficient		0.0004
Water Average velocity		0.02 m/day
Hydraulic Gradient		0.0004-0.0006
Average Porosity	Upper Dupitila	33%
	Lower Dupitila	41%
	Gondwana	20%
	Total area	21.05%
Direction of GW	Dupitila Fm	NE-SW
	Gondwana Fm	NW-SE

III. METHODOLOGY

Supportive data and base points

High resolution seismic data and coal seam data are used to envisage the subsurface vision through 3D modeling. The quality of the provided data has been authenticated by the QA program. This accuracy assessment process is simple and straightforward. The precision of the process is estimated by the ratio of measured value to true value, shown in table 3.

Table 3:
Quality Assessment program

DOB	True value (Coal seam data) (Source: W.A, GSB, CMC)	Measured value (Seismic data value) (Source : W.A,1993)	Accuracy
1	29.4	29.4	1
2	36.73	30.9	0.84
4	38.5	38.5	1
5	39.97	39.97	1
6	30.37	30.37	1
7	38.05	38.05	1
8	21.63	21.63	1
9	39.75	39.75	1
10	28.7	28.7	1
11	33.13	33.13	1
12	30.84	30.84	1
13	35.37	35.37	1
Total accuracy			0.9867

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3D modeling

The whole area is underlined by eight main litho units that vary randomly in perspective to depth and shows a clear distributional view on 3D block diagram (fig 4). The thickest coal layer (coal seam VI) is frequently distributed throughout the area. Sandy unit is the dominant unit that increases in thickness towards NW-SE direction and Kaolinized sand is almost absent towards north, northeast and northwest side (fig 5, 6).

Considering the formational units, the area is consisted of four formations with some specific hydrological characteristics. The major aquifer, Upper Dupitila Aquifer is directed to the coal layer towards the Northern side and some of the portion of the North-Eastern side (fig 7, 8, 10) due to the absence of the aquiclude, Lower Dupitila formation.

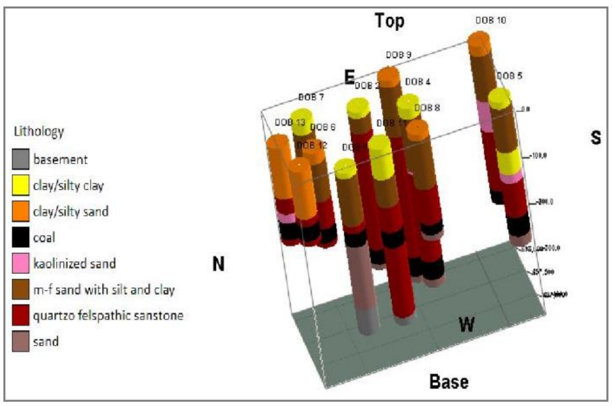


Fig 4: Multi log block diagram per borehole

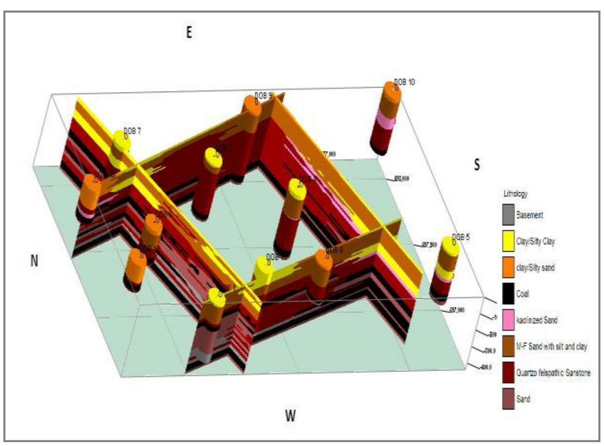


Fig 5: Lithological variations of the entire mine area

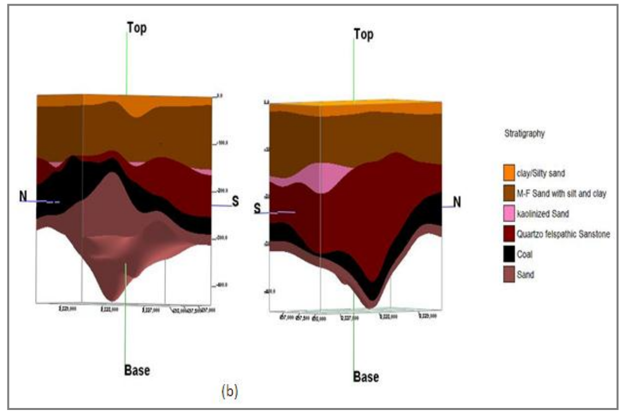
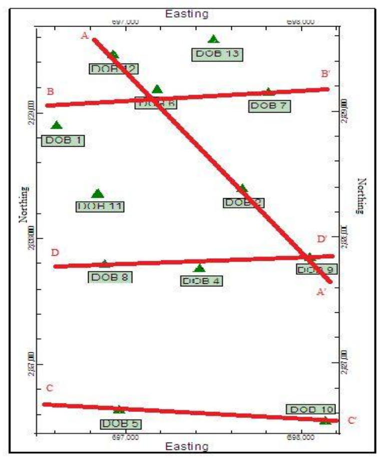
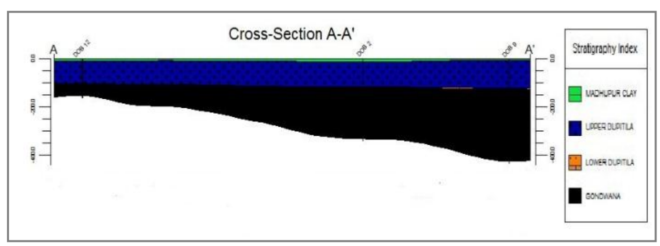
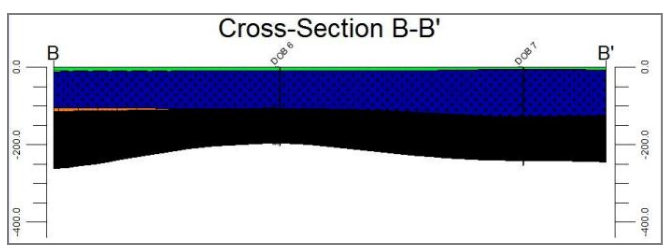


Fig 6: 3D subsurface model showing the lithological changes







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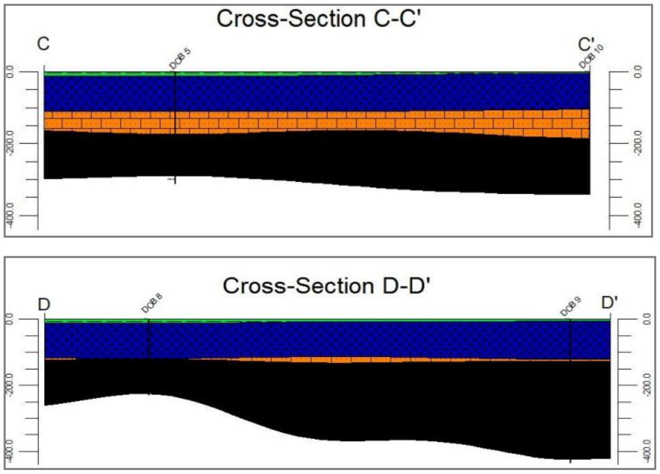

Fig 7: Geological Cross-sections along A-A’, B-B’, C-C’ and D-D’ lines, shows the absence and presence of LDT unit

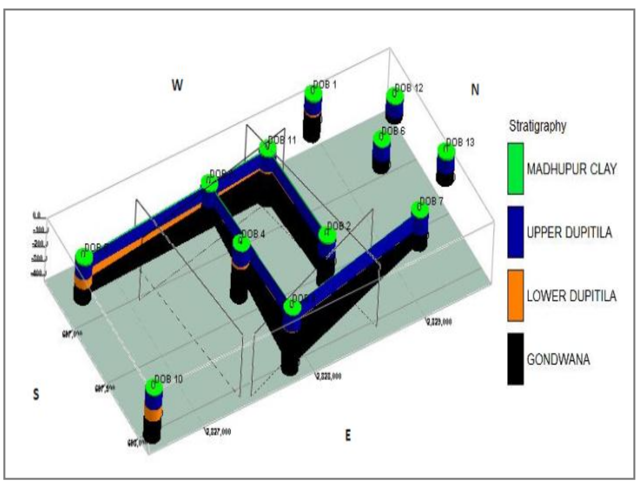

Fig 8: Formation changes of the entire mine area

From the provided cross-sections, the presence and absence of the Lower Dupitila Aquiclude in between UDT and Gondwana unit is clear.

The geometry of the four formations lying on the area is shown in fig 9. The thickest zone of the aquifer has reached in the NE part (range 120-124 m) of the basin whereas the relatively shallower zone has been found in the NW side (range 94-102m). On the other hand, the thickness of the Gondwana aquifer varies from 240- 350 m (fig 11).

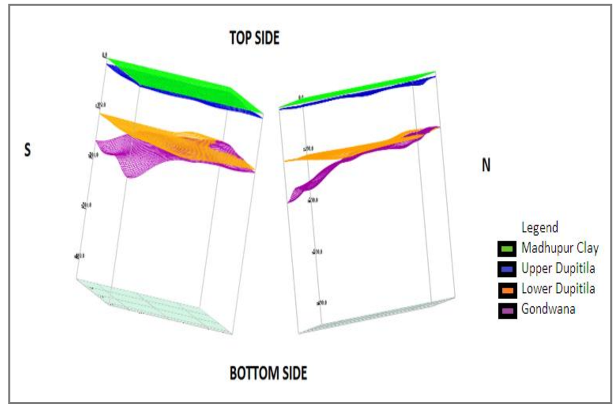

Fig 9: Geometry of the interbedded formations

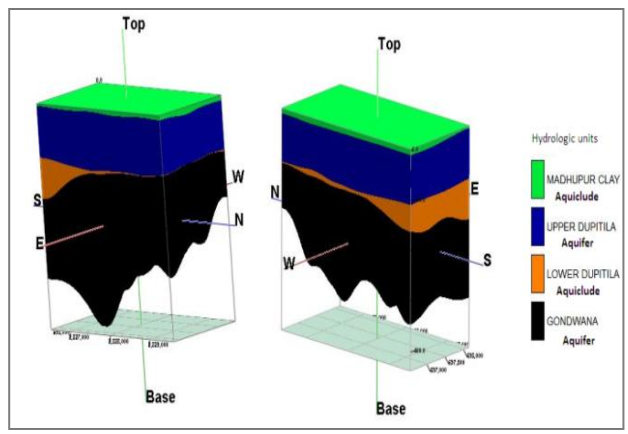

Fig 10: 3D Hydrological model

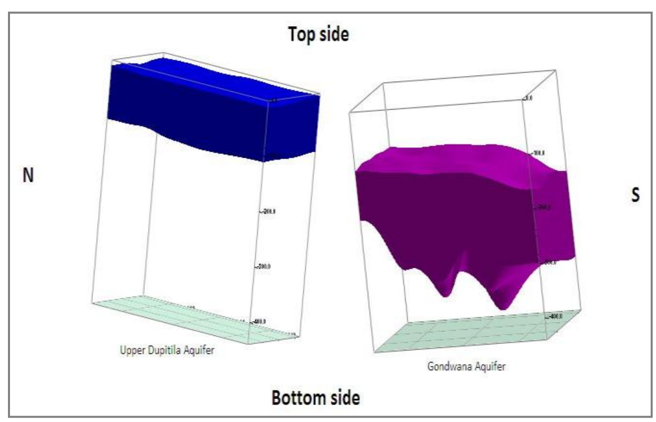

Fig 11: Thickness variation of two aquifers

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IV. Complexity On Mining Operation

N-side mining operation will or may be jeopardizing due to collateral position (fig 12, 13) of the Upper Dupitila aquifer to the coal bearing Gondwana unit. Additionally, the variation of the water inflow also threats the current exploration activities. Sudden water inrush and flooding can happen at any time during the mining operation. In some severe case, partly or totally damaging the design of the mine, lowering the strength of the backup strata, toxicant the surrounding area due to injection of the ground water to the side abutment strata can also occur. Sometimes this situation may cause several deaths of miners. Without having proper management of the aquifer, the mine has to be closed prior to its tentative closure time.

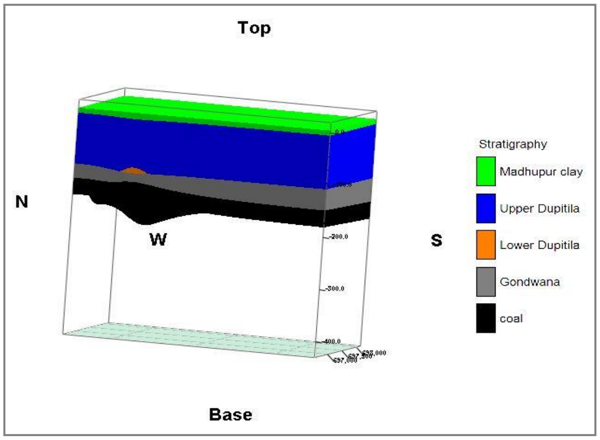

Fig 12: Formation delineation model of Northern part

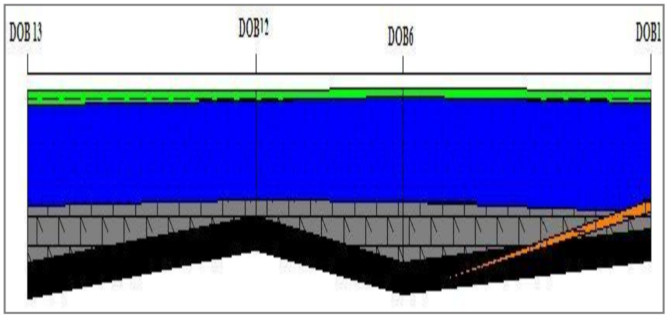

Fig 13: Cross- section of Northern part

On the other hand, the contamination of the aquifer (fig 14) due to mining operation, aberrantly lowering the water table and changing the stream flow due to over exploitation can take place. So the mine shall be provided with proper drainage system for the expected water inflow.

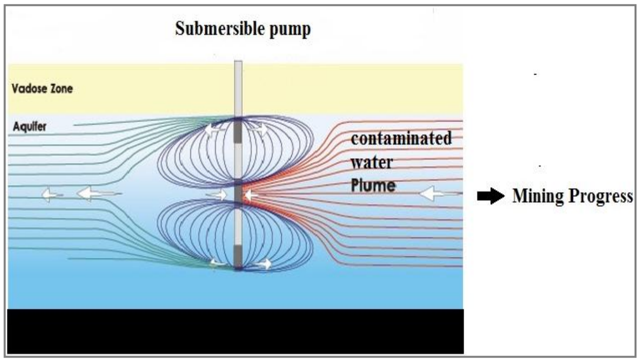

Fig 14: Contamination of aquifer due to the injection of toxic mining water to fresh water

V. Possible Mitigations

Controlling the water pressure is one of the major concerns to miners during mining procedure. Rendering mitigation, dewatering process should be continuously done throughout the area especially at the time of mining. The water level must be drawn down beneath the coal deposits (fig 15). The amount of total discharge water should accurately be estimated and according to the daily need, the amount of daily discharge rate should be planned first. But if the daily discharge rate exceeds the surrounding needs for mining suitability, then the excess water might be captured for future use by some modern technologies. The pump out water can be used for domestic purpose, irrigation and pit-head Barapukuria power station.

Proper design of the dewatering system according to the daily draw down rate is another concern. In that connection, the number of pumping out well, frequent well distribution and efficiency need to be kept in mind. The number of well should be increased in the NE part of the basin where the maximum thickness, almost about 124m, of the aquifer indoors (fig 16).

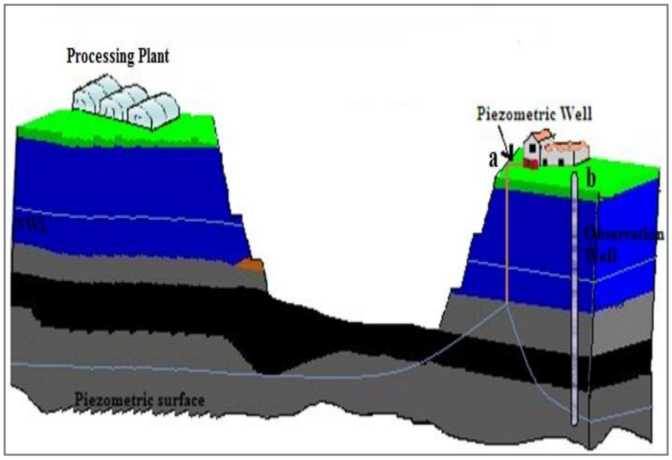

Fig 15: Lowering down the water level through dewatering process during mining; water is pumping out through a) piezometric well and the lowering water level should be monitored through b) observation well

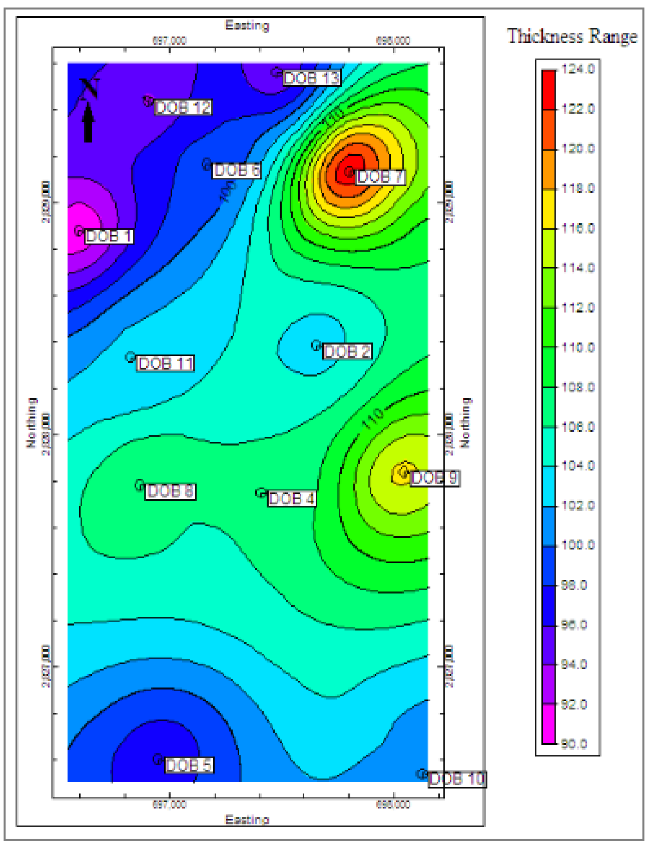

Fig 16: Thickness variation of UDT aquifer

To restrict the seasonal change of that area in some degree, artificial recharge can also be done. The contamination of the aquifer and lowering the surrounding water table due to the mining operation can be minimized or managed by isolating the mine area into an impermeable membrane.

But mining hazards especially related to water can often occur at any time that may create a danger situation of mine. So the regular monitoring of the aquifer and strictly following the mining rules are requisite. The mine should run with some pre-caution for handling the unexpected water inrush. On the basis of the Mine Regulation of Labour Safety and Management (1992), this article proposed some guiding principles for opening up mine as a both short and long term remediation program.

1. The mine shall be provided with drawing archives to keep the surveying and geological maps in accordance with the requirements of regulation concerned (article 51).
2. Extraction works shall be subject to the drawing, elaborating the conditions of geology and extraction (article 57) and one of the important parameters of technical design is maintenance of drainage system (article 60).
3. During drilling, the effect of water or gas, if any, shall be recorded instantly (article 67) and investigatory boreholes shall be drilled deep to the proposed shaft depth in order to clarify the hydro-geology and engineering geology. Number of the boreholes shall be increased if the geological conditions are complicated. Space from centre of the designed shaft to the investigatory borehole shall be within 20m (article 73).
4. Each and every aquifer, ascertained by the drilling, shall be investigated to determine the depth and thickness of aquifer, static level of water, volume of inflow, pressure and temperature of water, maintenance of borehole wall, chemical composition of water and its erodibility of cement (article 77).
5. The aquifer layers shall be insulated from boreholes by casing- lowering, mud-grouting, cementation or other chemical method.
6. The mine should measure the water inflow at least twice a year and conduct the chemical analysis of water at least once a year (article 684).
7. The main pump station shall be provided with the following number of pumps for normal operation (article 710).

- 2 out of 3 pumps installed in pump station
- 2 sets out of pump sets installed in pump stations

8. The main pumping equipment shall be provided with at least 2 lines of independent discharging pipes; the capacity of each pipeline being no less than the total nominal discharging capacity of working pumps. The velocity of water flow shall be less than 3m/sec (article 711).

VI. CONCLUSION

The country has agonizing energy dilemma from a long period of time, as because apathy of using the indigenous coal resources properly; nonetheless according to BCMCL, burgeon of the Barapukuria coal mine will or may be neutralized the bane of this sector. A small scale opening up proposal had been given off on the sequential previous article of the authors. But the recent study find out that the head to head contact of aquifer and coal deposits may beset the mining progress; even so it may become one of the reasons of tentative closure of mine if the necessary precautions are not pursuit. Dewatering process with an appropriate limit of drawdown should be done as a subsidiary part of plan and a proper management plant must be launched to controlling this pumping out water. Proper management of extracted water is , now, among the major concerns of mining, but the long-term solution of coal sector does not depend only on the debates of whether it could be manageable or not. Moreover, despite of this uncertainty, the mine sector should go forward by following the mine policy of international standard.

VII. RECOMMENDATIONS

The energy-ridden Bangladesh, which is struggling hard with her development, cannot afford to make mistakes regarding the isolation of the coal sector. Ascertaining the long-term energy security of the country, the government needs to take some concrete steps. The following outlines are recommended:

a) In spite of the pejorative side, it is possible flourishing the mine towards Northern side in order to soothing the impasse of energy and also expanding the scope of coal sector.
b) Under the proper design, dewatering process should be done within the ultimate limit of drawdown and the extracted water then, can be utilized in a significant way.
c) The density of the pumping out well is needed to be increased towards the NE side in where aquifer reached its thickest level.
d) Auditing, based on the EIA standard, should be done in regular basis.

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