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Coal Bed Methane Extraction Proposal of Khalashpir Coal Field, Rangpur, Bangladesh.

Hridita Ferdous, Md. Mobinul Haque, Wahida Akhtar

Abstract— This paper is a primary approach to make assessment on utilizing deep seated coal by considering coal bed methane technology in Khalashpir Coal Field. A drilling pathway along with procedure has been suggested. The inclination angle of wells has been calculated using various types of equations for planning the drilling well path for creating hydraulic fractures in coal zones for extracting adsorbed methane gas.

Index Terms— Coal Bed Methane, Directional Drilling, Hydraulic Fracturing, Khalashpir Coal field, Bangladesh Coal Mine, Fracking, Adsorbed Methane, Natural Gas, Bangladesh.

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1 Introduction

As conventional energy resources are depleting in Bangladesh, it is utterly an appropriate time to seek unconventional energy resources to meet up the already heightened energy demand in this over populated country. As an attempt to facilitate the search for alternative, coal bed methane is highly suggested to combat the present energy crisis scenario. With the perception of contributing in combatting the present situation of energy crisis, assessments have been made on the prospect of coal bed methane gas in Khalashpir coal field, Rangpur, Bangladesh and combination of hydraulic fracturing along with directional drilling has been suggested to extract the adsorbed methane gas in the deep seated coal beds.
Our study area is in Rangpur district lies between latitudes 25^{0}23’14” and 25^{0}30’0”N and longitude 89^{0}09’12” and 89^{0}15’0”E.

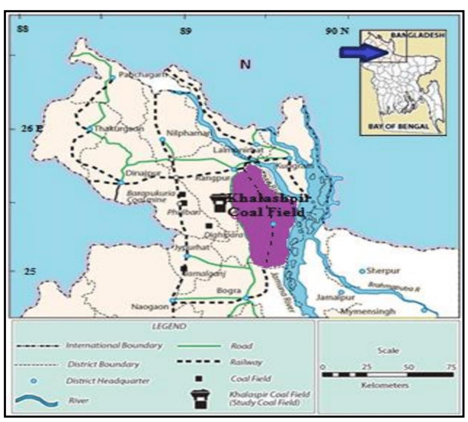

Figure 1: Location Map of Khalashpir Coal Field

- Hridita Ferdous has pursued her masters’ degree program in Petroleum Geology from University of Dhaka, Bagladesh. E-mail: hridz0809@gmail.com
- Md. Mobinul Haque has pursued his bachelor degree program in Electrical and Electronics Engineering from Bangladesh University of Engineering & Technology, Bangladesh. E-mail: mobin.eee.green@gmail.com
- WahidaAkhtar has pursued her masters’ degree program in Petroleum Geology from University of Dhaka, Bagladesh. E-mail: wakhtar19@gmail.com

2 Proposed Methodology

Extraction of coal bed methane requires drilling wells into coal beds and withdraws formation water contained in the coal seam to reduce the hydrostatic pressure and allow the adsorbed methane gas to get released from coal (Wheaton, 2005-2006).
In seismic survey, NW-SE trending several normal faults along with three major faults has been identified in khalashpir coal basin (IMC Group Consulting Limited, 2009).

- To avoid the fault zones while drilling for coal bed methane and minimize chances to contaminate local aquifer, directional drilling method has been proposed along with the following reasons:
- With proper materials, directional drilling will have longer lifespan and calculative placement would prevent damages associated with installation
- Compared to traditional drilling method, directional rilling would cause lesser dirt displacement which leads to lesser dirt to burial and disposal.
- Having shorter lifespan and lesser dirt burial and disposal, the project cost will be eventually lower.
- As directional drilling pushes the soil to the side instead of bringing it to the surface, chances of soil contamination spreading above the ground is lesser.

3 Planning Drill Path

The prime factor in cost of directional wells is the horizontal distance to target. The objective of this study is to present the calculation of well path to define the trajectory where pay zone path would be optimum and cost effective.
Vertical wells are usually defined as wells within inclination angle of 5^{0}. Wells with a section having inclination angle greater than 85^{0} is termed as

horizontal well (Farha, 2013).
For deep seated coal seems in khalashpir coal basin, let us consider the following picture (Figure-2) as well path of directional drilling, where:

TVD= Total Vertical Distance
KOP= Kick Off Point
d= Depth of Coal Seam
i= Inclination angle
r= Radius of the curvature
t= Thickness of coal seam
q= Build up Rate (^{0}/30m)
D_h= Deviation of the wellbore from the vertical (Horizontal Displacemnent)

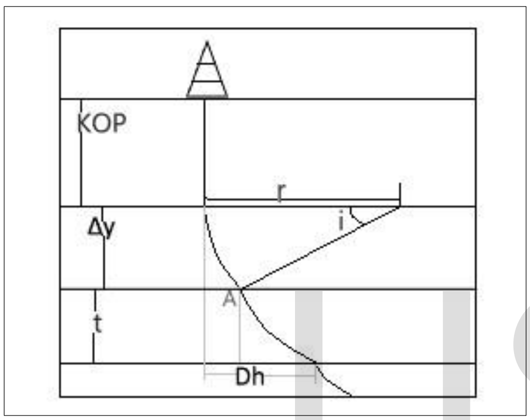

Figure 2: Well Path Design

So,
d = KOP
TVD = d + t

Now, Radius of the curvature,

$$r = (180°)/\pi \ \times 1/q$$

First, let us consider the Δy zone first to establish relations between the parameters (Figure-3).

$$\text{Now, } \alpha 1 + 90° - i = 90°$$

$$\text{So, } \boldsymbol{\alpha_1 = i}$$

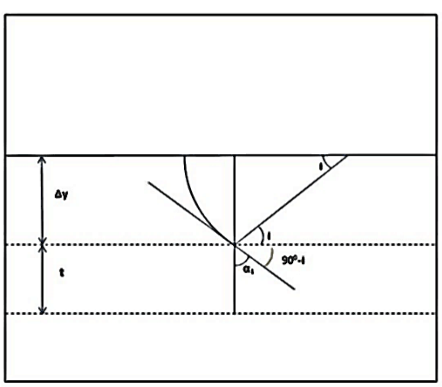

Figure 4: Inclination angle in Δy zone

3.1 Establishing relation between parameters considering R> D_h:

For establishing relationship between mentioned parameters, let us consider the first scenario where R> D_h.

3.1.1. Deflection Angle

In figure-4, let us assume that α1 deviates at the angle of α and the inclination angle becomes α2 while entering from Δy zone to t zone.

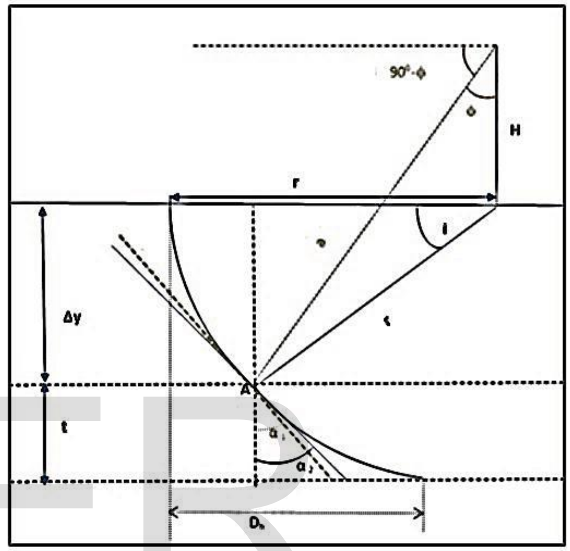

Figure 3: Drilling Well Path for R> Dh.

As per Cosine Rule,

$$\cos\emptyset = (a^2 + H^2 - r^2)/2aH$$

$$\emptyset = \cos^{-1}\{(a^2 + H^2 - r^2)/2aH\}$$

$$\alpha 2 = 90° - \cos^{-1}\{(a^2 + H^2 - r^2)/2aH\}$$

From figure-4, for R> D_h,

$$Deflection\ angle, \alpha = \alpha 2 - \alpha 1$$

3.1.2. Establishing a-H relation

Let us consider Figure-4 for establishing a-H relationship for planning the drilling well assuming the path would be circular.
As per cosine rule,

$$\cos(90° + i) = (r^2 + H^2 - a^2)/2rH$$

$$-\sin i = (r^2 + H^2 - a^2)/2rH$$

$$\Delta y/r = (r^2 + H^2 - a^2)/2rH$$

$$2\Delta yH = (r^2 + H^2 - a^2)$$

$$H^2 + 2\Delta yH + (r^2 - a^2) = 0$$

$$H = \{-2\Delta y \pm \sqrt{4\Delta y^2 - 4(r^2 - a^2)}\}/2$$

$$H = -\Delta y \pm \sqrt{(\Delta y^2) + a^2 - r^2}\ [H > 0]$$

$$\textbf{So, } \boldsymbol{H = -\Delta y + \sqrt{(\Delta y^2) + a^2 - r^2}}$$

3.1.3. Maximizing Arc length of Production zone:

For increasing production path way, calculations were made to maximize the arc length of production zone. Considering figure-5 for this calculation;

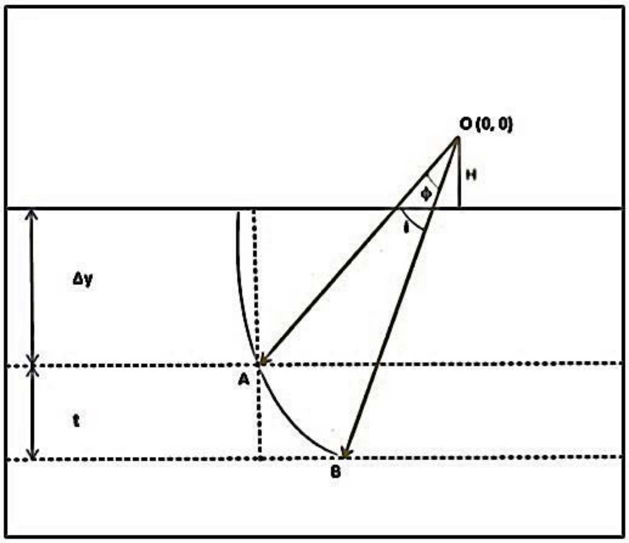

Figure 5: Maximizing Arc length for R> D_h.

$$\overrightarrow{OA} = \hat{x}\, r cos i - (\Delta y + H)\hat{y}$$

Co-ordinate of point B,

$$y = -(H + \Delta y + t)$$
$$x^2 + y^2 = a^2$$
$$x = \sqrt{a^2 - (H + \Delta y + t)^2}$$

Now,

$$\overrightarrow{OB} = \{-\sqrt{a^2 - (H + \Delta y + t)^2}\}\hat{x} - (H + \Delta y + t)\hat{y}$$
$$\overrightarrow{OA}.\overrightarrow{OB} = \{\sqrt{a^2 - (H + \Delta y + t)^2}\} r \cos i + (\Delta y + H)(H + \Delta y + t)$$

$$|\overrightarrow{OA}| = |\overrightarrow{OB}| = a$$

$$Arc\ Length, AB = a\emptyset$$

So,

$$S = a\ \cos^{-1}(\overrightarrow{OA}.\overrightarrow{OB}/a^2)$$

$$S = a\ \cos^{-1}[\{(\sqrt{a^2 - (H + \Delta y + t)^2}\ r\ \cos i + (\Delta y + H)(\Delta y + H + T)\}/a^2]$$

For Maximum S,

$$ds/da = 0\,, d^2s/d^2a < 0$$

Where $\emptyset$ is in radians

For the Horizontal Displacement, D_h;

$$Dh = \left| r - \sqrt{a^2 - (H + \Delta y + t)^2} \right|$$

3.2. Establishing relation between parameters considering R<D_h:

For planning the well path and establishing relationship between parameters, let us consider other scenario where R< D_h.

3.2.1. Deflection Angle

In figure-6, let us assume that α_1 deviates at the angle of α and the inclination angle becomes α_2 while entering from Δy zone to t zone.

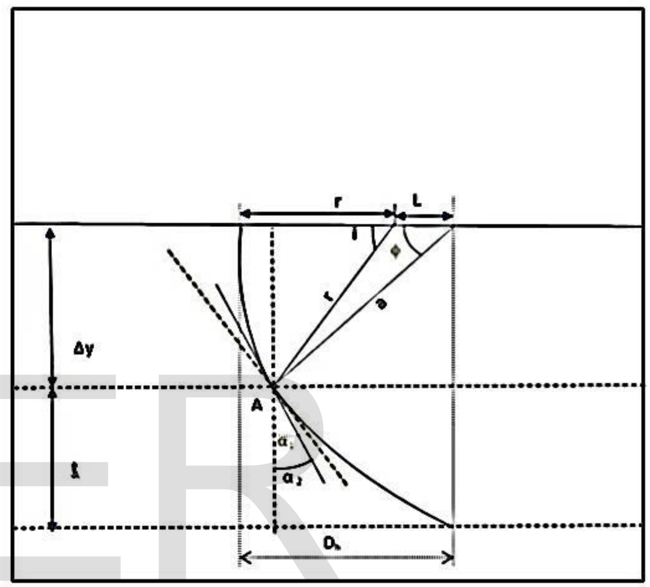

Figure 6: Drilling Well Path for R< D_h

According to cosine rule,

$$\cos\emptyset = (a^2 + L^2 - r^2)/2aL$$
$$\emptyset = \cos^{-1}\{(a^2 + L^2 - r^2)/2aL\}$$
$$\alpha = \alpha 1 - \alpha 2 = i - \cos^{-1}\{(a^2 + L^2 - r^2)/2aL\}$$

3.2.2. Establishing a-L relation

Let us consider Figure-6 for establishing a-L relationship for planning the drilling well assuming the path would be circular.

As per cosine rule,

$$\cos(180 - i) = (r^2 + L^2 - a^2)/2rL$$
$$-\cos i = (r^2 + L^2 - a^2)/2rL$$
$$-\sqrt{1 - Sin^2 i} = (r^2 + L^2 - a^2)/2rL$$
$$-\sqrt{r^2 - (\Delta y)^2} = (r^2 + L^2 - a^2)/2L$$
$$L^2 + \left\{2\sqrt{r^2 - (\Delta y)^2}\right\}L + (r^2 - a^2) = 0$$
$$L = [-2\sqrt{r^2 - (\Delta y)^2} \pm \sqrt{4\{r^2 - (\Delta y)^2\} - 4(r^2 - a^2)}\,]/2$$
$$L = -\sqrt{r^2 - (\Delta y)^2} + \sqrt{a^2 - (\Delta y)^2}\ [For\ L > 0]$$

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3.2.3. Maximizing Arc length of Production zone

For increasing production path way, calculations were made to maximize the arc length of production zone.

Considering figure-7 for this calculation;

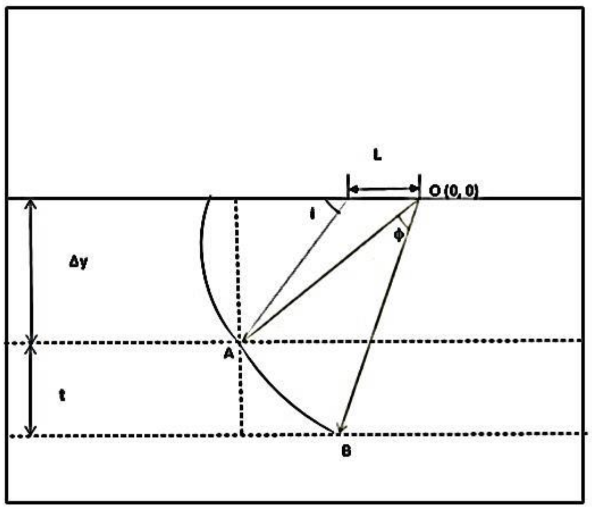

Figure 7: Maximizing Arc length for R<D_h

$$\overrightarrow{OA} = -(L + r\cos i)\,\hat{x} - (\Delta y)\hat{y}$$

Co-ordinate point of B,

$$y = -(\Delta y + t)$$
$$x^2 + y^2 = a^2$$
$$x = -\sqrt{a^2 - (\Delta y + t)^2}$$
$$\overrightarrow{OB} = \left\{-\sqrt{a^2 - (\Delta y + t)^2}\right\}\hat{x} - (\Delta y + t)\hat{y}$$
$$\overrightarrow{OA}.\overrightarrow{OB} = (L + r\cos i)\left\{\sqrt{a^2 - (\Delta y + t)^2}\right\} + \Delta y\,(\Delta y + t)$$

So,

$$S = a\ \cos^{-1}[\{(L + r\cos i)\sqrt{a^2 - (\Delta y + t)^2} + \Delta y\,(\Delta y + t)\}/a^2]$$

For Maximum S,

$$ds/da = 0\,, d^2s/d^2a < 0$$

Where ∅ is in radians

For the Horizontal Displacement, D_h;

$$Dh = \left|r + L - \sqrt{a^2 - (\Delta y + t)^2}\right|$$

4 Theoretical Findings

4.1. Well Drilling Procedure

The first step in making a drilling program for a CBM well involves gathering info concerning existing wells during a given space which incorporates reservoir depths and pressures, drilling histories and environmental issues. a vital side in drilling frontier or appraisal wells is to stay the drilling procedures comparatively straightforward.

In directional drilling method, the well is turned horizontally at depth. because the mechanical drawing of the well are going to be at larger depth, it'll embody a vertical half moreover.

Directional well will be able to reach a much wider area of coal and will extract more methane gas, so fewer number of wells will be needed for production. If drilled directionally, the well will be able to access the methane surrounding the entire portion of the horizontally drilled section.

4.2. Hydraulic Fracturing Process

Hydraulic fracturing also known as hydro-fracturing, hydro-fracking, fracking or fraccing is a well-stimulation technique in which rock is fractured by a pressurized liquid. For selecting hydraulic fracturing fluid in Khalashpir Coal seam for extraction of CBM gas, some theoretical findings concluded.

4.2.1. Selection of Fracturing Fluid

Fracturing Fluid selection is an important aspect for Hydraulic Fracturing process. The ideal fracturing fluid should:

- Transport the propping agent in the fracture.
- Compatible with the formation rock and fluid.
- Be able to generate enough pressure drop along the fracture to create a wide fracture.
- Be able to minimize friction pressure losses during injection.
- Formulate the use of chemical additives that are approved by the local environmental regulations.
- Be able to exhibit controlled-break to a low-viscosity fluid for cleanup after the treatment.
- Be cost-effective.

In Khalaspir coal basin, Water-based fracturing fluids - uncrosslinked polymers and "slickwater" can be used as fracturing fluid as in recent years, these treatments have become a standard technique in fracture stimulation and yield economically viable production. As the anticipated proppant-suspension capacity of slickwater fluids is quite low, linear (uncrosslinked) gels can also be used.

4.2.2. Fracture Direction

In Khalaspir coalfield all the coal zone depths ranges from around 200-400m which can be termed as Shallow depth zones from coal bed methane's extraction perspective. Here, horizontal fractures tend to be created because the hydraulically induced pressure will force the walls of the fracture to open in the direction of least stress which is vertical for shallow depth (less than 1000m), creating a horizontal fracture.

5 Hypothetical Working Model

If the khalashpir coal field undergoes CBM extraction the following process is suggested for enhancing the fractures in coal seam and producing coalbed gas from underground coal zones.

5.1. Investigating and Surveying The Area

For any mining program, gravity and magnetic survey is the first step in measure the. Though the report of geological survey of Bangladesh covers most of the necessary required data yet some investigations can be made for assuring the acquired data.
Surveys can be made for knowing present status of population and suitable mining area as CBM extraction requires large equipment which will not be convenient in densely populated area. Electromagnetic surveys can be done to locate utilities and pipelines.

5.2. Analyze Core Data

As several wells have been drilled before in this area, core samples can be achieved. The core sample must be analyzed to examine unit strength of the coal, volume of gas adsorbed on wet coal in cubic centimeter per gram (cc/g), volume of gas adsorbed on dry coal in cubic centimeter per gram (cc/g) to get more accurate gas content estimation. Then if the adsorbed gas is economically viable for mining, drilling program can be planned.

5.3. Planning The Directional Drilling

It is hypothetically suggested that directional drilling will result maximum production as the thickness of the coal beds are thin to moderate. So if CBM extraction undergoes in Khalashpir coal basin directional drilling is recommended from this study and well panning has been established by various calculations.

5.4. Planning the well path

To plan a directional well path, the location of kick off point, the length of tangent section, and the inclination angle at which the well will enter to the coal zone must be known. The relation of inclination angle of the well and deflection angle has been established in this paper.

5.5. Drilling and Initial Well Testing

Wells have to be drilled vertically to the “kick-off point” at this point the bore stats inclining. When the target distance will be reached, the drill pipes will have to be removed and steel casing will have to be inserted. Then the casing will have to be cemented to place.
A wire line tester can be used to measure the static pressures of all the permeable layers of interest. Pressure versus depth plots will help to establish the formation fluid gradients and identify the fluid contacts in the reservoir.

5.6. Well Completion and Perforating the Casing

The first step in completing the well is to making a connection between the final casing and coal zone. Then a perforating gun can be used to create holes in the casing. The gun will have to be placed lower into a targeted position within the horizontal portion of the well. Then, an electrical current would need to be sent down the well to set off small explosive charge. This will create tiny holes. The holes created by the “perforating” gun serve two purposes: they provide access for the fracturing fluid to enter the formation and subsequently allow natural gas to enter the wellbore.

5.7. Fracturing the coal Zone and injecting fracturing fluid:

Fracturing fluids containing proppants, can be injected under high pressure into the well. The fracturing fluids will have to be injected into the subsurface at a rate and pressure that are too high for the targeted coal zone to accept. As the resistance to the injected fluids increases, the pressure in the injecting well will increase to a level that exceeds the breakdown pressure of the rocks in the targeted coal zone, and the rocks breakdown. The propant can be fine sands that will be mixed with the used fracturing fluid.
This process will have to repeat to create desired fractures in all the targeted zones.

5.8. Removal of Fracturing Fluid and pumping out ground water

After hydraulic fracturing is completed, all of the equipment placed between fracturing stages are drilled out to remove the restrictions in the wellbore. The completed well is then opened up to safely remove the fracturing fluid so that methane can be extracted. The fracturing fluid that is recovered from each well is treated and reused in future fracturing jobs by recycling system. To initiate methane production, groundwater is also removed to create declination of pressure.

5.9 Methane Production

The groundwater and fracturing fluid will have to be pumped until the pressure declines to the point that methane begins to desorb from the coal. When the producing starts the coal bed methane can directly send to pipeline as it has no hydrogen sulfide which requires refining (Energy, 2015).

6. Discussions

All the coal zones of Khalashpir Coal Basin are around 200-400m deep with very few exceptions. The coal zones are also not very thick. If we see the depth and thickness range, we can conclude that CBM development may not be the best way to use coal resource in Khalashpir area though detail investigation is needed for accurate consideration. However, if Khalashpir coal basin undergoes hydraulic fracturing technology for CBM extraction the following issues must be considered.

6.1. Fracture Behavior

Fracture behavior is of interest because it contributes to an understanding of the potential impact of fracturing fluid injection on underground source of drinking Water (USDW); the opportunities for fracture connections among USDW suffering from the extent to which a hydraulically induced fracture grows. Specifically, when hydraulic fracturing fluids are injected into formations that are not themselves USDWs, the following scenarios are of potential concern:

- The hydraulically elicited fracture might extend from the target formation into a USDW.
- The hydraulically induced fracture may connect with natural (existing) fracture systems and/or porous and permeable formations, which may facilitate the movement of fracturing fluids into a USDW

6.2. Fracturing Fluid Recovery

A variety of site-specific factors may have influential effect the recovery efficiency of fracturing fluids. These factors are needed to be considered which are summarized as follows:
Fluid Leakoff: Fluids can “leakoff” from the primary hydraulically induced fracture into smaller secondary fractures. Then fluids might get trapped in the secondary fractures and/or pores of porous rock. The injection of hydraulic fracturing fluid with high pressure can force the fracturing fluids to be transported deep into secondary fractures. The cleats in coal are presumed to play an important role in leakoff.
Check-Valve Effect: Fluids can become entrapped due to the “check-valve effect,” wherein fractures narrow again after the injection of fracturing fluid ceases, formation pressure decreases, and extraction of methane and groundwater begins. A check-valve effect may occurs when natural or induced fractures open and allow fluids to flow through with high fracturing pressure, yet subsequently prevent the fluids from flowing back towards the production well as they close after fracturing pressure decreases.
Adsorption and chemical reactions: Some fluid constituents can become adsorbed to coal or react chemically with the formation.
Movement of Fluids outside the Capture Zone: Some volume of the fluids, moving along the hydraulically induced fracture, may move beyond the capture zone of the pumping well, and thus cannot be recovered during fluid recovery.
Incomplete Mixing of Fracturing Fluids with Water: Some fluid constituents may not completely mix with groundwater and therefore would be difficult to recover during production pumping.

6.3. Environmental Impact of the process:

Development of CBM resources does carry substantial environmental risk. As with the production of natural gas from conventional reservoirs, CBM development results in surface disturbance from the construction of roads, well pads, pipelines, and other facilities. Traffic on lease access roads and human activities at well sites and facilities may disturb human and wildlife. Likewise, CBM production might result air pollution from the exhaust gases emitted from compressor used, leakage of methane, and dust, and the operation of pumps, compressors, and other machinery may generates noise pollution. The chief environmental concerns from CBM production, however, arise from the eligible management to dispose of large volumes of produced water, from the potential for the uncontrolled release of gas from the coal reservoir to shallow groundwater, from the potential for drawdown of shallow groundwater, and from the potential for spcific well completion technologies to affect shallow groundwater.

7. Recommendations

CBM is a very good resource of alternative energy but the prospect of Khalashpir coal basin in this perspective are moderately potential though detail study is required to be utterly sure.
If CBM technology is introduced in Khalashpir coal basin by hydraulic fracturing then monitoring fracturing fluid must be done very carefully. Radiotracers can be used to monitor the fracturing fluid yet preserving groundwater

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without contaminating must be the top priority.
In Hydraulic Fracturing process, tailings dams should be capped with at least one meter of inert (no carbonaceous) material to avoid spontaneous combustions.
In-situ coal pillars can be constructed and gas can be extracted from specific area of underground coal to avoid subsidence. The area of in-situ pillars and production zone must be constructed so that maximum production can be done along with avoiding subsidence.
Fluid propagation must be measured so that the injected fluid do not get highly away from the capture zone and the casing of well must be done carefully to prevent the leakage of methane gas to the ground water.
The locations chosen for compressor stations and other noisy equipment for drilling can be selected to minimize their impact on the acoustic environment.
The drilling well and extraction process must be planned in a way so there is minimum chance for occurring environmental problems.

8. Conclusion

The Khalashpir coal field, with 147 million tons of coal (Techno-economic Feasibility Study of Khalashpir Coal Mine Project, Dhaka, Bangladesh, 2006), has moderate potential for CBM extraction. The CBM technology has established in coal fields in all around the world where either coal depth are not viable for conventional coal mining or the thickness of the coal is very high to contain economically viable adsorb gas. The depth and thickness is an important concern in CBM issue though CBM has been extracted in many parts of the world from shallower depth and fewer thicknesses. In this paper, directional drilling technique has been suggested to maximize production as in directional drilling production zone is greater than conventional vertical drilling with minimum number of production wells. Calculations have been made to plan the well path and maximize the arc length of the production zone. Government patronization and co-operation is much needed for focusing on alternative energy resource in Khalashpir coal basin. The viability of CBM must be compared with the viability of Underground coal gasification and conventional coal mining so that the most potential technique can be scrutinized and implementation can be done as per potential and energy demand of the country.

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